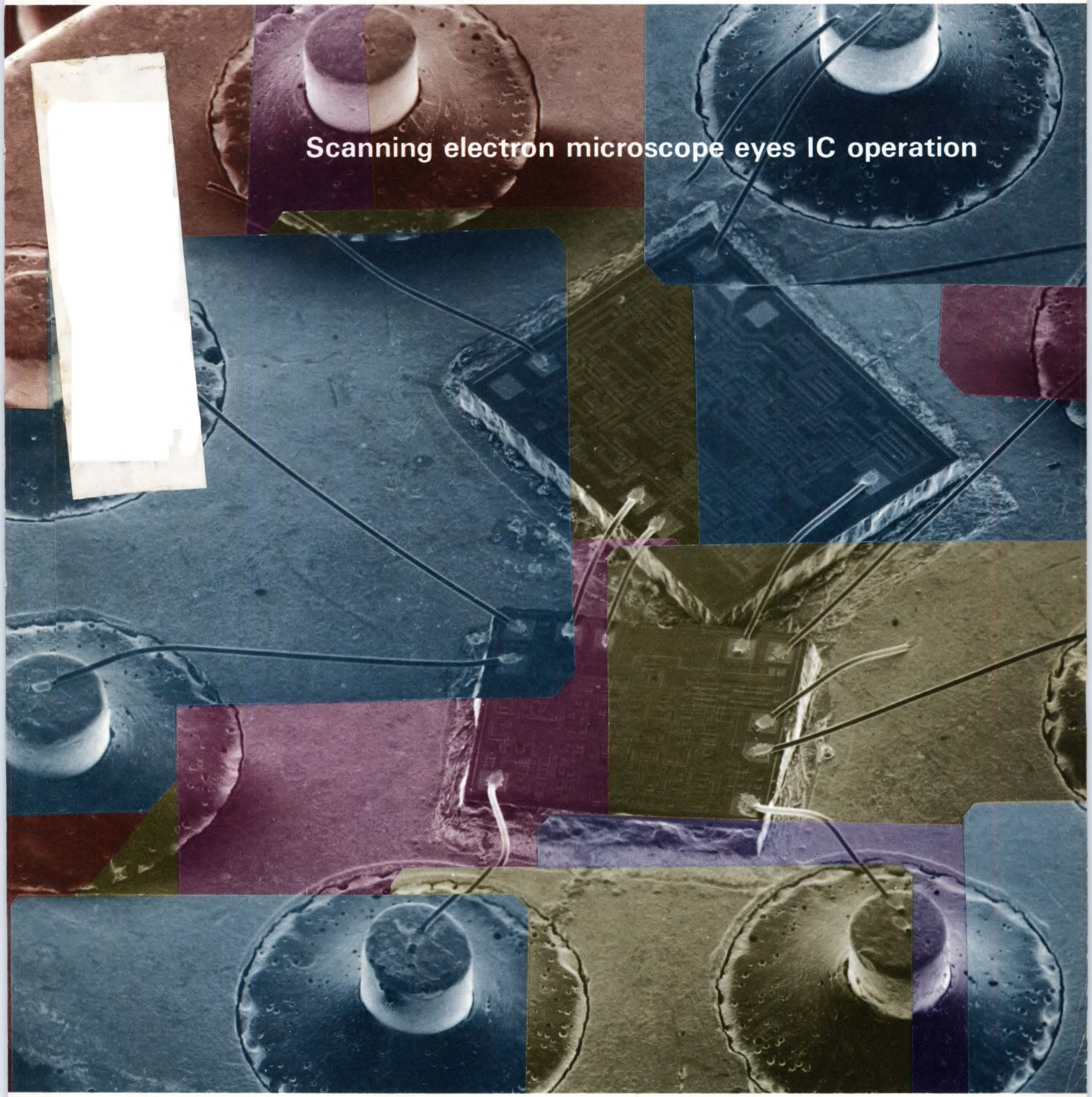
EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

EDN

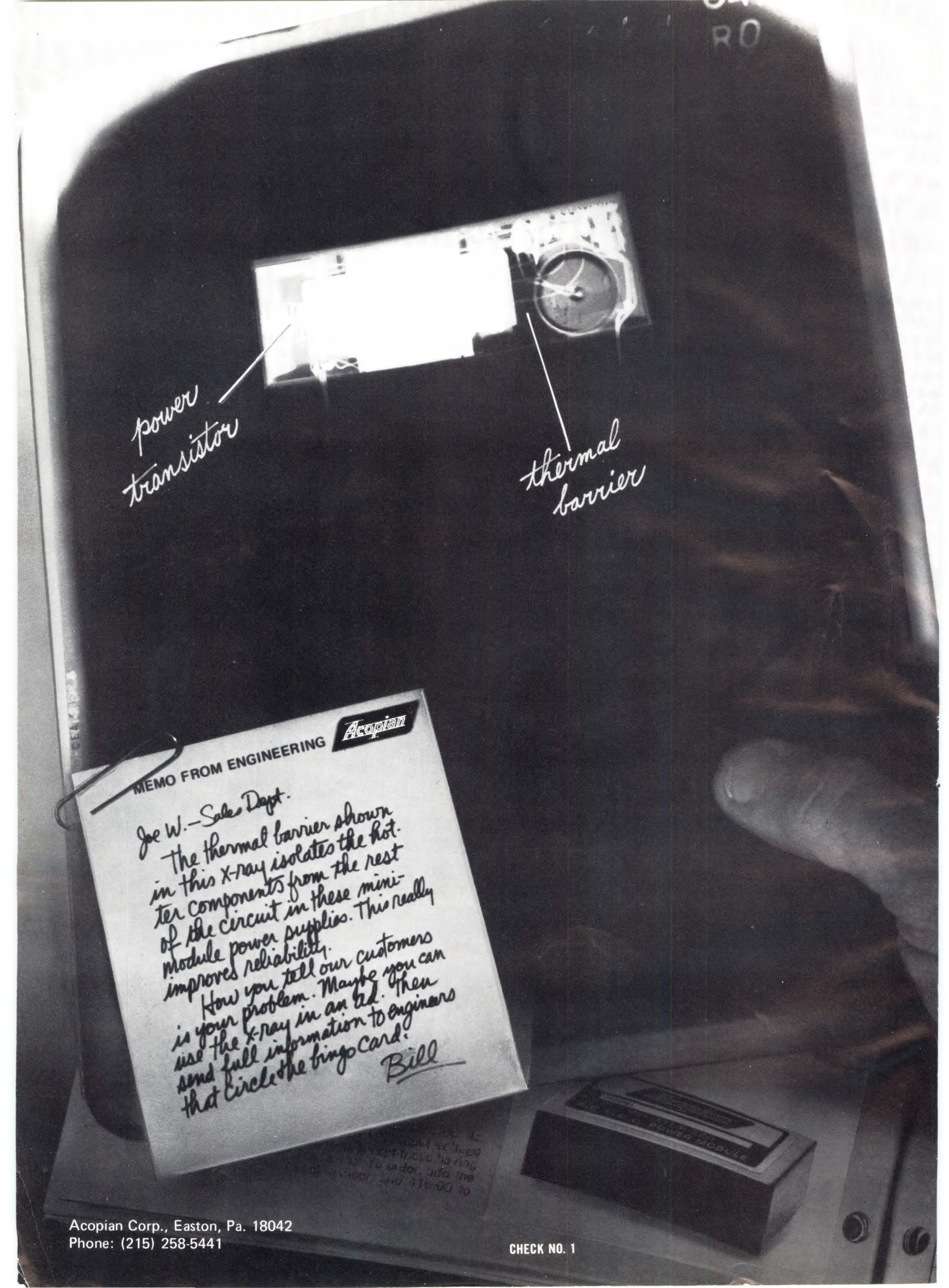
Users look critically at bench test equipment

A potpourri of uses for IC timers



A CAHNERS PUBLICATION

MARCH 5, 1973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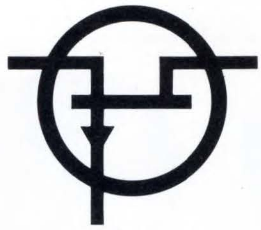
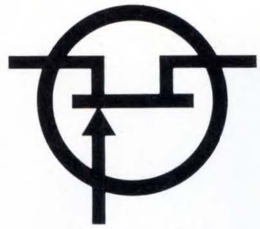


P-Channel
JFET



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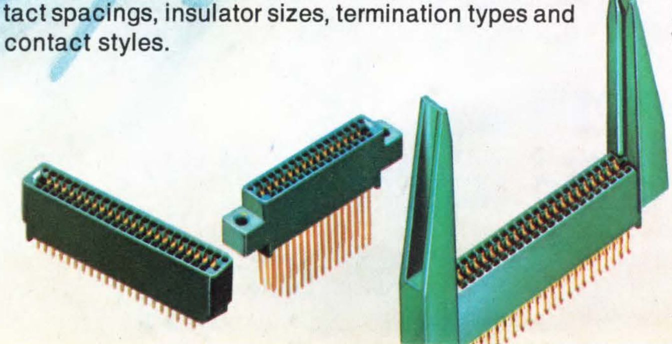
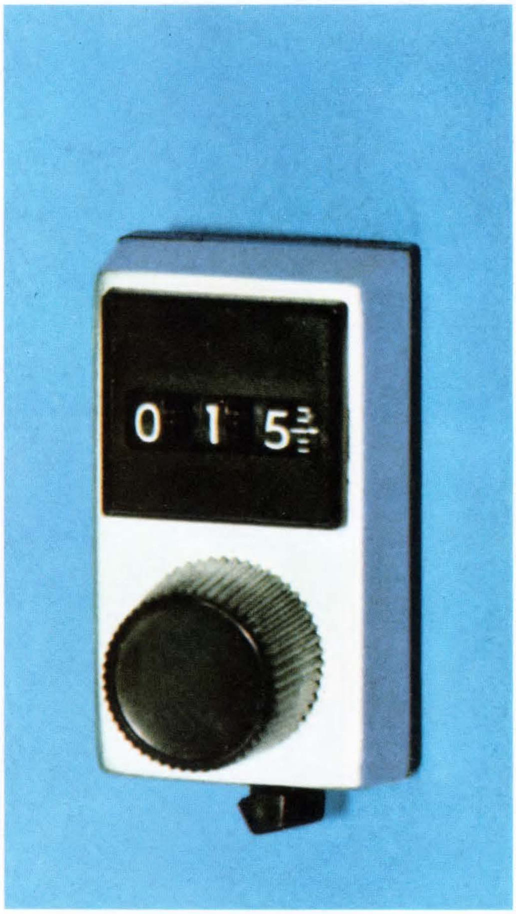


TRW® CINCH CONNECTORS

CHECK NO. 9

Your new panel beauty kit...



The Spectrol Model 15 Dial!

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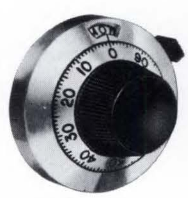
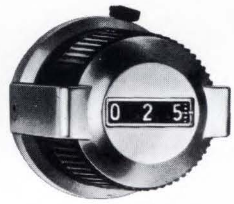
Model 11



Model 21



Model 25

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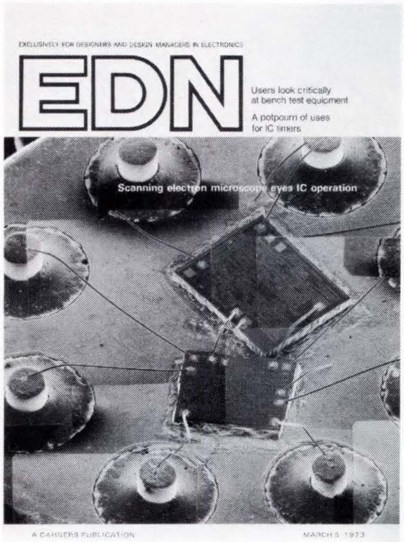
CHECK NO. 10

MARCH 5, 1973
VOLUME 18, NUMBER 5

EDN with EEE
EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS



COVER

Using a technique much like photo mapping, electron microscopist Dick Flutie of Harris Semiconductor put together this photo mosaic of a Harris FET-input op amp for our cover. At 10,000x, the TO-5 header produced a photo over 12 inches across. For a size reference, those wires are 1/3 the diameter of a human hair. See related story on pg. 14.

DESIGN NEWS

DESIGN FEATURES

PROGRESS IN PRODUCTS

DESIGN PRODUCTS

DESIGN DEPARTMENTS

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Perkin-Elmer would like to send you a data sheet on the new Varidac Converters. Write or call Perkin-Elmer Corporation, Electronic Products Division, Main Ave., Norwalk, Conn. 06856. Tel. (203) 762-4786.

PERKIN-ELMER

CHECK NO. 11


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CHECK NO. 12

EDITORIAL

Let's get off the roller coaster

Have you looked at the "want ads" lately? Chances are that you have—if only as a habit developed during the recent recession.

On the surface, the ads paint a rather rosey picture of the engineering employment situation. Job openings are plentiful in most sections of the country, with the exception of a few very specialized engineering disciplines. Even the professional recruiters are beginning to appear again from wherever they go during hard times.

What the want ads don't show is the approximately 10,000 engineers in the country who are out of work. Granted, this represents only 1% of the nation's one million engineers. But this is a rather special 1% considering their education, and the blood, sweat, tears and money that went into it.

Many of these unemployed engineers are, by choice, out of engineering for good, having embarked on other careers because of both necessity and disillusionment. Others are out of the field for good, not by choice, but because they became overly specialized or sidetracked into peripheral areas that existed only because of the largess of Federal spending.

What exists, therefore, is a state of approaching employment stability, but at the expense of thousands of engineers who were brought to the feast but sacrificed during the famine.

Bad as this situation is, it could serve a positive purpose were we to learn a lesson from it. But such does not seem to be the case. Statistics are being ballyhooed that predict an acute shortage of engineers in the years ahead. For example, the Bureau of Labor Statistics sees a future demand for 48,000 engineers a year. And although 43,000 were graduated last year, this will drop to 32,000 in four years based on current enrollment. The result—a shortage of engineers in the future. The remedy—increase the enrollment in engineering schools.

We question, first, the validity of the figures. Are 48,000 engineers really going to be needed? Or is it really 30,000 engineers—and 18,000 technicians, specifications writers, sales types, etc.?

We also question the engineering schools rushing pell-mell to expand their enrollments, at least without carefully evaluating the future requirements themselves. Schools are very capable of overproducing when they think there's a need for a certain discipline. Just look around at the excess of teachers today.

The solution, we feel, is for all concerned to move slowly and be conservative in their thinking wherever possible. This includes industry in estimating its future needs, government in gathering statistics, schools in expanding their enrollment and even students in selecting a career.

Frank Egan

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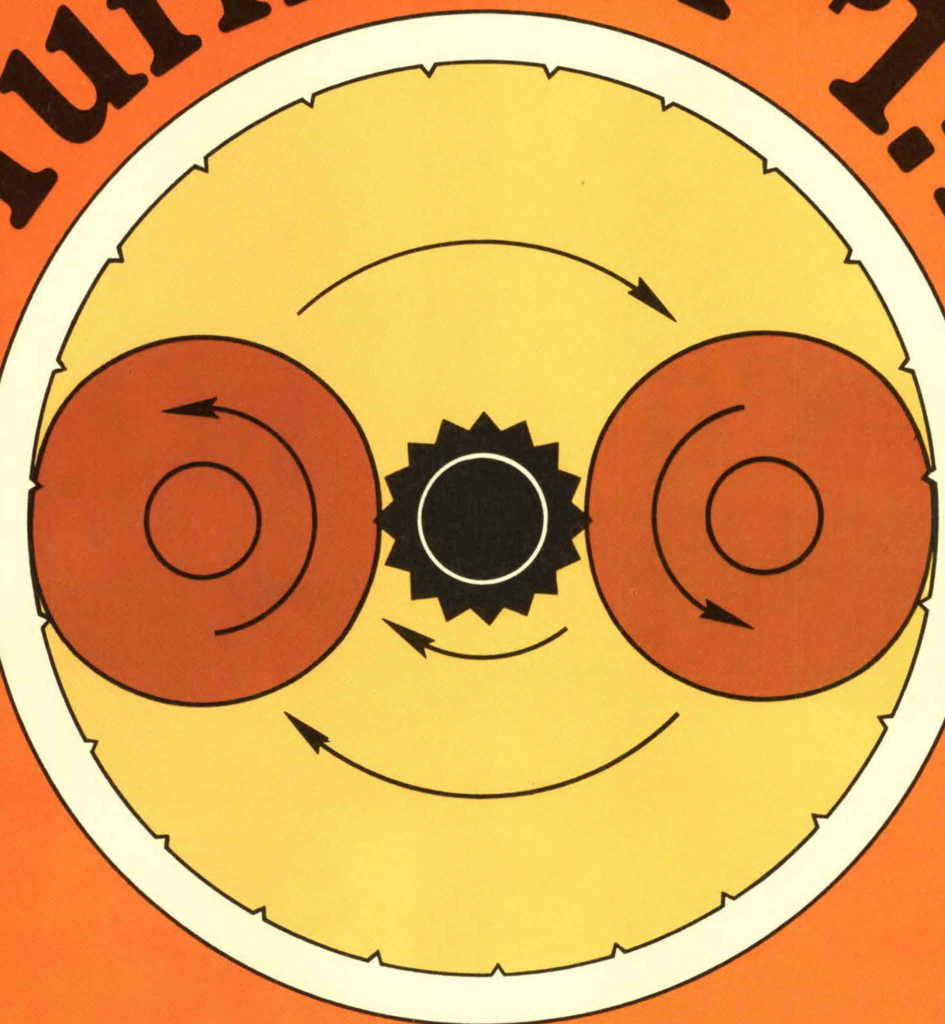
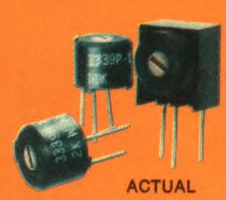


MODEL
3339



ACTUAL
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Meet a model of setability...

the smallest low-price multi-turn potentiometer on the market.

You can be four times as sure of balancing critical circuitry with this cermet trimmer, Model 3339. Why? An ingenious drive mechanism (patent 3,614,703) gives you four mechanical turns to traverse the element.

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Call, or write, your nearest Bourns sales office for more data on this multi-turn in a single-turn package. (Top-adjust size: .30″ dia. x .25″ high. Side-adjust size: .31″ x .32″ x .38″ high)

Available from your Bourns distributor.

BOURNS

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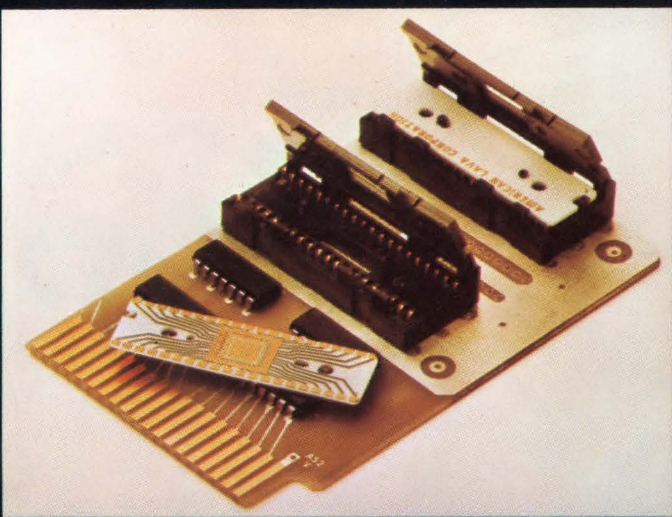
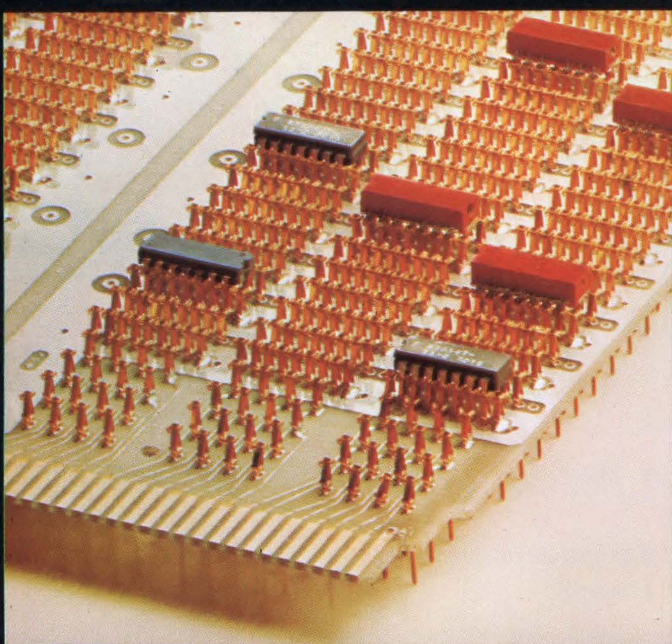
CHECK NO. 16

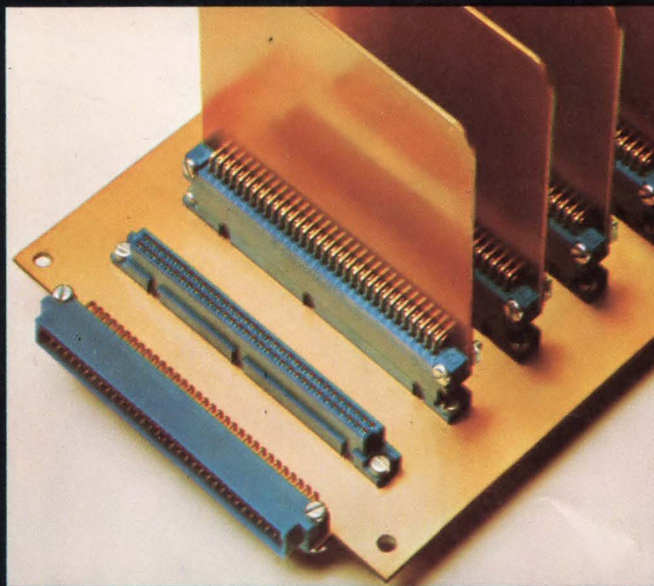
New from Amphenol's Spectrum



level 1

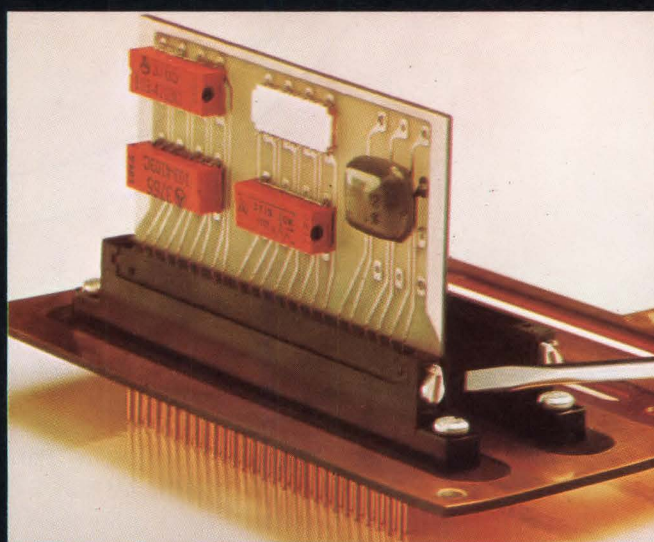
MOS/LSI Planar Plug-In connectors (above) for leadless, flat mount ceramic substrates. Permits fast, easy replacement of IC package, no screws, has snap-down lid. ■ Free-standing terminal (below) terminates IC's to PC boards for lowest total systems cost.





level 2

Box contact connectors (above) intermate with .025" square or round contacts. Low insertion force. Terminations for crimp, wire wrapping or wave solder. ■ Zero insertion force connectors (below) improve PC board and connector life by eliminating strain and wear.



Above are seven new ideas from Amphenol Industrial Division's Spectrum of interconnection capability.

Amphenol's SPECTRUM offers you *all four* levels of interconnections from our unmatched breadth of product line:

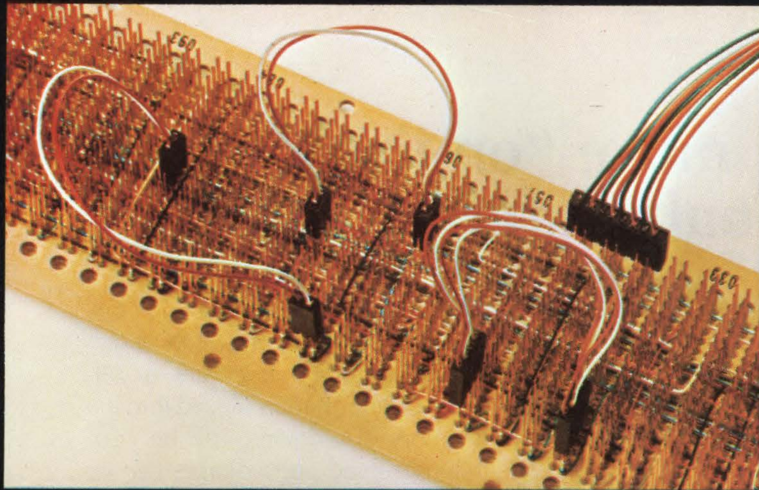
Level 1 . . . DEVICE TO BOARD OR CHASSIS. We offer interconnections for components such as tubes, relays, transistors, IC packages, trimmers, resistors or capacitors to a PC board or chassis.

Level 2 . . . BOARD TO MOTHERBOARD OR BACK PLANE. We offer interconnections for PC boards or other sub-circuit modules to a motherboard or to a back plane.

Level 3 . . . MOTHERBOARD OR BACK PLANE WIRING. We offer interconnections for levels to each other and to other sub-circuits with multi-layer circuit boards, wire wrapping, clip terminations, jumper techniques and dip-soldering.

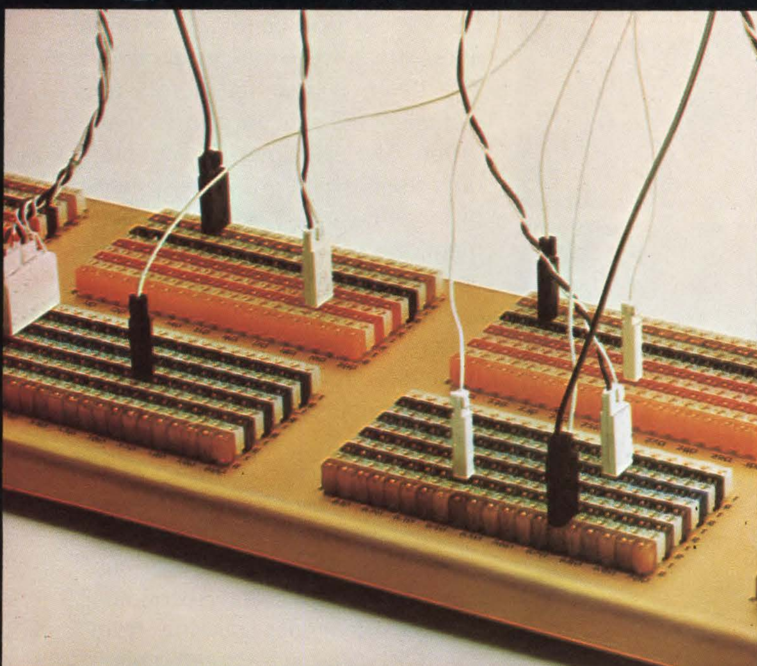
Level 4 . . . INPUT/OUTPUT CONNECTIONS. We offer interconnections for power and signals to and from a system. This interface may be between sub-assemblies within the same enclosure or between individual units.

# of interconnections.



level 3

Low cost strip connectors (above) are used as jumpers in back plane wiring. Intermates with .025″ square or round posts. ■ Circuit Concentration Bay (below) consists of wire wrappable panels that are five times as compact as the telephone distribution frames they replace.



level 4

Modular Integral Connector concept lets you make your own pin & socket connector to fit your needs. Five contact sizes, thousands of combinations. Sufficient components for six connectors in handy MIC-KIT. Design and assemble your own prototypes.

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Therefore we approach your interconnection needs with complete open-mindedness.

For more new ideas and specific information, write for your copy of "SPECTRUM." Amphenol Industrial Division, Bunker Ramo Corp., 1830 South 54th Ave., Chicago, Illinois 60650.

BUNKER RAMO AMPHENOL

CHECK NO. 17

Electron microscopes move "on line" at semiconductor manufacturers

One of the most amazing shows that you'll ever see was demonstrated to EDN late last year when Dr. S. K. Behera of Microsystems International, Ltd., in Ottawa, let us see a fifteen minute video-tape of a 1k-bit semiconductor RAM. The tape was made by a scanning electron microscope (SEM) operating in what is known as the voltage-contrast mode. Dr. Behera had worked out a method of strobing his SEM video display in order to slow down the apparent operating speed of the RAM. The result was that when a negative voltage was applied, the semiconductor surface turned white so you could watch the address, read, write and storage elements in operation.

Aside from the entertainment value, it turns out that most large manufacturers of semiconductors now use SEMs routinely for evaluation of all of their new products and processes.

The techniques developed by Dr. Behera allow MIL's circuit designer to verify the operational integrity of his device as well as to readily detect design errors, masking faults or potential reliability problems. All new memory circuits designed by Microsystems are currently subjected to this analysis. Doubtless, this technique helped MIL greatly in producing their new 4k-bit RAM. It also gives the device-analysis engineer a powerful tool for quickly determining failure mechanisms in defective devices.

MIL has used the SEM voltage-contrast techniques to analyze the performance of MOS and bipolar memories with densities up to 4k bits. Using external-driving circuitry, information moving through each stage of a shift register, or patterns of information placed into the memory of a device, can be visually observed and voltages can be measured with an accuracy of 50 mV anywhere on the surface of the device.

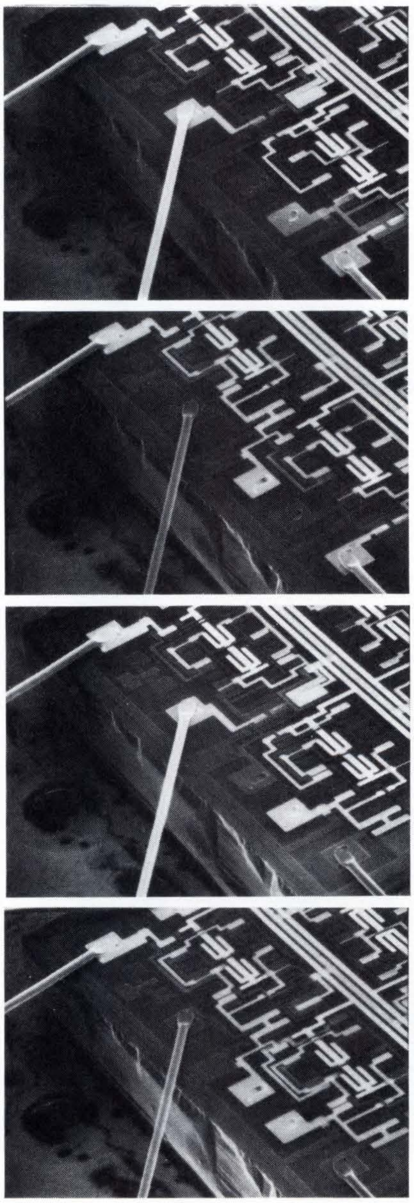


Fig. 1—Two stages of an MOS flip-flop array shown in voltage-contrast mode scanning electron microscope photos. Shown clockwise from the left are count input, ÷2 output and ÷4 output wires. The more white the wires appear, the more negative is their voltage potential. Note the alternating ONEs and ZEROs depicted by the ÷2 and ÷4 wires. Photos by Tony Gonzales, Motorola.

The SEM consists of a tungsten-filament electron source with three electromagnetic lenses which focus the electron beam to a spot of approximately 10 nM in diameter. The beam is scanned across the surface of the specimen in a square raster. The specimen is mounted on a stage which gives five degrees of movement (X, Y and Z displacement, plus tilt and rotation). The complete system is operated in a vacuum of 10^{-5} torr. The rest of the system consists of detection, amplification and imaging of the signals produced by the electron beam.

The high-energy (2 to 10 KeV) beam of primary electrons interact with the surface of the solid specimen, producing a variety of signals which include: secondary electrons (energies ranging from 1.0 to 50 eV), back scattered electrons (energy approximately equal to the primary electrons—dependent on the atomic number of the elements), X-rays (used in composition analysis), light, absorbed electron current (dependent on the atomic number of the elements) and beam induced current.

For studying semiconductor devices, three modes of operation are used. These are: the emissive mode, the voltage contrast mode and the beam induced current mode.

The emissive mode

The secondary electrons, being of low energy, originate within 100Å of the specimen surface. These electrons are detected by a scintillator-photomultiplier system. The signal is amplified and fed to a CRT to modulate the intensity and thus provide an image of the surface of the specimen. The high resolution and large depth of focus obtained from the scanning electron microscope provides a 3-dimensional like image of the specimen on the CRT.

The emissive mode of operation is very useful in the study of the surface of semiconductor devices. Typical areas of application are in process control and quality control for: identifying pinholes, voids, undercutting and general cosmetics of metallization and oxides; electromigration; bond characteristics and intermetallic formations.

Most of the large semiconductor manufacturers presently use this technique on a routine basis to ensure integrity of all manufacturing process steps.

Voltage contrast mode

The secondary electrons emitted from the specimen surface are very sensitive to surface potentials. When a semiconductor device is biased, areas of different potentials give rise to contrast in the image. The contrast is caused by changes in the collection efficiency of the detector which in turn are caused by changes in the path of the secondary electrons. The construction of the detector system is such that negative potentials appear bright and positive potentials dark.

Using this mode of operation, it is possible to observe and determine the exact functional behavior of large-scale integrated circuits. Recent work has shown that functional behavior of MOS memories (RAMs, ROMs and pROMs) and shift registers can be studied successfully and that defect analysis time can be reduced immensley. By properly calibrating the contrast, it is possible to use the electron beam as a floating probe to measure threshold voltages, transfer characteristics of inverters and internally generated clock voltages

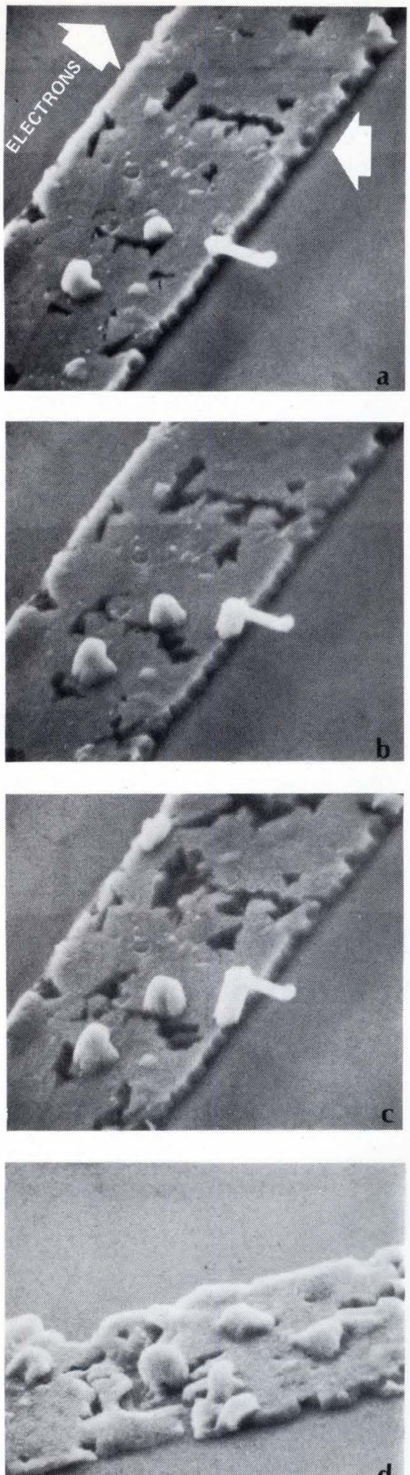


Fig. 2—Aluminum conductors on ICs have failed because voids which occur during manufacture tend to migrate against the electron flow and group together. In this sequence from Motorola photo (**a**), taken after 28 minutes of high-current operation, a group of these voids begin to form about 2/3 of the way up the conductor. Photo (**b**) (40 min.) and (**c**) (60 min.) show these voids growing, reducing the cross sectional area of the 1 × 12 μm stripe. Photo (**d**) shows another view of the failure which occurred in just over one hour. By operating at current densities of 2 million A/cm^2, a failure that would take years in normal operation can be reproduced in a very short period. Photos by Motorola.

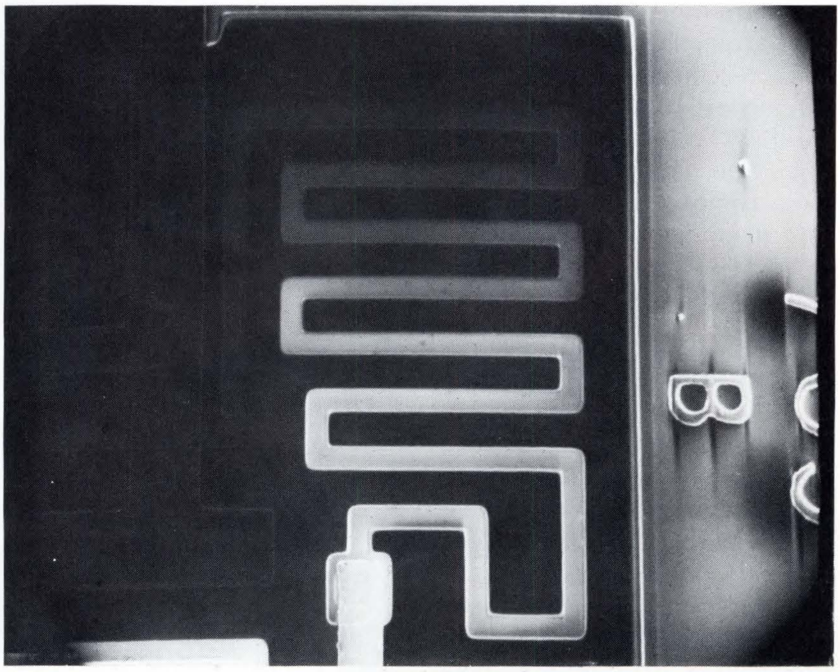


Fig. 3—A single diffused resistor from an IC op amp of the 709 type, photographed with an SEM under the voltage-contrast mode, clearly depicts the distributed voltage drops along its entire length. The black (top) portion is the most positive and the white (bottom) portion is the most negative. Photo by Dr. S. K. Behera, Microsystems International.

at any point within the complex device circuit.

Using a TV scanner in the system, video-tape recordings can be made of a device operation, which becomes very useful for studying dynamic properties of the circuit. Stroboscopic techniques (i.e., strobing the electron beam at the operating frequency of the device) are used to freeze the image for studying devices at their maximum operating frequency.

Beam induced current mode

The primary electron beam, when bombarding the surface of a semiconductor device, produces hole-electron pairs. In the neutral zone, these pairs recombine, whereas in p-n junction areas, due to the potentials involved, the carriers move in opposite directions resulting in a current, called the beam induced current.

This current can be amplified and imaged on the CRT to delineate the junctions of semiconductor devices. Properties, such as junction width, carrier life time and doping concentrations can be measured using this technique. Defects, such as ragged junctions, discontinuous junctions, shorted junctions and diffusion spikes, can be readily observed.

What of the future uses?

All of these features have been used to great advantage in producing more reliable semiconductor products and have made the SEM one of the most useful process controls available. It's greatest contribution may still be ahead.

Recently, researchers at IBM reported in *Scientific American* that they had succeeded in using an electron beam to expose the photoresist patterns on a semiconductor wafer and had produced devices an order of magnitude smaller than those possible using light-exposure techniques.

While an electron-beam device used for production purposes may not be an SEM in the strictest term, most of the techniques and components are identical.

Richard Flutie of Harris Semiconductor feels that an electron-beam generation of device geometries will be on the production line in just about three years. This may be the process breakthrough that allows such advancements as 30k-bit monolithic memories to become producible and start another round of LSI activity. — *BF* □

IC dual tracking regulators prove to be popular items yet few devices are interchangeable for second sourcing.

Three years ago the first dual tracking regulator IC offered the designer an alternative to bulky modules and the 1/2 pound discrete component regulator circuits. Silicon General's SG1501 was the first to appear; today there are thirty such devices to choose from. Apparently the demand for these compact dual regulators is hot; three semiconductor manufacturers are now pushing them and a fourth is about to enter the contest.

So far, the three manufacturers have copied some of each other's mistakes, and each has contributed a few on his own. Overall, there are many very excellent devices among these, but to date, not one of them has an alternative manufacturing source. Some are quite close to being plug-in second-source parts for another regulator chip of the thirty, but none match any other part well enough to be its second source. Perhaps Silicon General, Raytheon Semiconductor and Motorola Semiconductor are all groping for a dual tracking regulator design that everyone will want. Charging off

TABLE I

Part number	Description	Comments	Manufacturer
SG1501 SG2501 SG3501	The first monolithic DTVRs; lacked thermal shut-down, voltage adj. & balance adj.	The 1501 is mil. The 2501 & 3501 are com. The 3501 has slightly looser specs than the 2501	Silicon General
SG4501	100mA output current	The 4501 is the economy model available in 14-pin DIP and	
SG1501A SG2501A SG3501A	Same as non "A" versions, but with the above mentioned features added	TO-100 (10 lead TO-5)	
RC4194D RC4194TK	Similar to SG1501A series TO-66	But not a second source	Raytheon Semiconductor
RM4194D RM4194TK	14-pin DIP (TO-116) TO-66	M is for mil. C is for com.	
RC4195T RC4195TK RC4195DN	TO-100; the 95 is a fixed voltage regulator, unlike the 94 adjustable version	In a TO-66 package In an 8-pin mini DIP	
RM4195T RM4195TK RM4195DN		Mil versions, see the three preceeding devices	
MC1468L MC1468G MC1468R	Similar to SG1501 series TO-100 TO-66	But not a second source 1468s are com.	Motorola Semiconductor
MC1568L MC1568G MC1568R	TO-116 TO-100 TO-66	1568s are mil.	
LM125 LM126 LM127 LM128	+15V & −15V fixed +12V & −12V fixed +5V & −12V fixed Adj. from ±12V to ±30V	Not available for a few months yet For MOS memories, (LM127)	National Semiconductor

Table 1—The lineup of IC dual tracking voltage regulators shows little compatibility among devices.

TABLE II									
Representative part	V_{OUT} range (V)	V_{IN} range (V)	Output current max. (mA)	Power T_A @25°C (mW)	Derate above 25°C (mW/°C)	Package	Current limit adjustable?	Balance adjust available?	Temp. range
SG2501	10-23	12-30	100	680	5.4	TO-100	yes	yes	com
				1000	8.0	TO-116			
SG1501A	8-23	10-35	200	680	5.4	TO-100	yes	yes	mil
				1000	8.0	TO-116			
MC1468	14.5-20	16.5-30	100	800	5.4	TO-100	yes	yes	com
MC1468	14.5-20	16.5-30	100	1000	6.7	TO-116	yes	yes	com
MC1468	14.5-20	16.5-30	100	2400	16	TO-66	yes	yes	com
RM4194	0.05-42	9.5-45	200	3000	24	TO-66	yes	yes	mil
RC4194	0.05-32	9.5-35	200	3000	24	TO-66	yes	yes	com
RM4195	fixed	18-30	100	600	9	8-pin	no	yes	mil
						mini DIP	no	yes	mil
RM4195	fixed	18-30	100	800	5.4	TO-100	no	yes	mil
RM4195	fixed	18-30	100	2400	16	TO-66	no	yes	mil

Table 2—Overview of key parameters of available IC dual tracking voltage regulators.

Table 2—Overview of key parameters of available IC dual tracking voltage regulators.

in all directions still seems to be the trend. In about three months, National Semiconductor will be announcing twelve new parts, all quite different from the thirty devices now available.

The incompatible DTVRs

Silicon General's SG1501, the first IC DTVR, operates over the military temperature range and is nearly identical to its 0°C to 70°C counterparts the SG2501 and the SG3501. Except for compensating capacitor termination, it is pin-for-pin identical to Motorola's MC1468 and MC1568 in both the TO-116 ceramic DIPs (designated "L" suffix by Motorola and called a D-package by Silicon General) and the TO-100 metal can (designated case 603-3 or "G" suffix by Motorola and called a T-package by Silicon General). With the SG parts, the compensating capacitors must be connected from the "comp" inputs to the respective regulated outputs; whereas with the MC parts, the two capacitors go from the "comp" inputs to ground. A confidential source told EDN that it was Motorola's intention to second source the Silicon General parts, but they found the SG part design difficult to produce.

In redesigning the chip circuit for easier production, the frequency compensating capacitor connection compatibility was lost, hence, the Motorola parts are almost second sources for Silicon General's but not quite.

Raytheon decided to go its own route with the RC4194/RM4194, making no attempt at compatibility with either of the other two 14-pin DIPs (TO-116), or with the pin-outs of Motorola's "R" suffix power package. These three semiconductor houses all offer DTVRs in TO-100 metal cans, which are like TO-5s, but with ten leads instead of three.

Silicon General has a plastic 14-pin DIP version of the original 1501 design for commercial applications where cost is a major consideration. The SG4501 in its plastic 14-pin DIP N-package boasts output currents to 100 mA per side, 2V minimum input-output differential and 600 mW power dissipation at 25°C, derated at higher temperatures by 6.0 mW/°C up to +70°C.

This brings us to one of the most embarrassing dichotomies in spec sheet history. Many of these devices are specified to deliver 100 to 250 mA per side of the DTVR part, while the package's power dissipation limits their practical use to a fraction of such currents in many cases. Minimum and maximum differentials run 2 or 3V minimum and up to 27V—and even 45V. This means that in a typical application such as powering ±15V op amps on a pc card, you might need a cold hurricane-force air flow over your ±15V DTVR to get the electrical current you need.

Speaking of specification sheet

dichotomies, many of these dual tracking voltage regulator ICs boast of both high-output current capability and good regulation parameters, measured with 0 or 1 mA load current. In addition, high-input voltage capability and high-output current do not usually go well together with regulator power dissipation in the order of 1/2 to 3W.

The most common application is of course, $\pm$15V for op amps. With unregulated V_{in} specified at $\pm$45V on a regulator that can deliver 250 mA, that's up to 15W to be dissipated by the regulator. This tends to defeat the benefits of its compact size (power dissipation distribution with local regulators then means local heat sinks and perhaps local fans).

Most of the DTVRs have both current-limit and over-temperature protection on chip. Some are fixed at $\pm$15V, others are adjustable. Some have a balance adjust input capable of making the plus and minus voltages asymmetrical.

Raytheon is introducing an 8-pin mini DIP DTVR with internal current limit, thermal shut down and compensation (it has optional comp inputs which are needed if an external pass transistor booster is used). Their RC4195/RM4195 will be offered in both TO-66 and 14-pin DIP as well as the 8-pin mini DIP. It is a fixed $\pm$15V regulator which requires only two external components, a 10 μF solid-tantalum capacitor from each output to ground. The simple-to-use fixed voltage DTVR, like the 4195 looks like the next trend in DTVR design since National Semiconductor plans to announce a series of them in a few months.

ICDTVRs, present & future

As the above summary and tables indicate, there is a large choice of IC dual tracking regulators now on the market. They all have about the same basic features, but vary in pin configuration and in electrical parameters. Each of the three suppliers has its own chip design and packaging ideas, but none of the parts are second source for any other. We have witnessed similar lack of direction at the beginnings of other new product areas; history repeats itself as each competing vendor strives to get a better product on the market faster than the next guy.

The X501As have upgraded output current capacity over their predecessors, the X501s, but to date, Silicon General has not offered the device in a power package like the TO-66 offered by Raytheon and Motorola. The X501A chip is willing, but its TO-100 and TO-116 packages can't handle much heat transfer. Silicon General is off the track for those designers who want heavier current capability; in most cases it's not easy to get 200 mA at 15V from a regulator output without a good means of taking away the regulator's heat. A 4194 in the TO-66 power package can deliver 200 mA from each output with few heat dissipation problems; likewise the 1468/1568, in its power package, is rated at 100 mA per side. The 501A/2501A/3501A is specified for 200 mA per output, but so far it is not available in a package that can reasonably handle the heat.

The 4194 is not internally set for $\pm$15V outputs as are the others. It has the widest output voltage range, $\pm$0.05 to $\pm$32V (commercial), and to $\pm$42V with the military version. The SG2501A can be adjusted from 8 to 23V; and the 1468 and 1568 can be adjusted from 14.5 to 20V. Using its balance adjust input, the 4194 can be asymmetrically trimmed to +5V and −12V for MOS memories.

Raytheon's 4195 may mark a turning point in the proliferation of IC dual tracking voltage regulators. Like the 3-pin single regulators (see pg. 52, EDN, Feb 20, 1973), the voltage is fixed and external components are reduced to a minimum (2 bypass capacitors on the 2 outputs), plus current limit and over-temperature protection are included on the chip. It is available in a mini DIP and no compensating capacitors are needed unless external current-boost pass transistors are used. The 4195 is specified at 100 mA output current per side, limited in the case of the mini DIP to about 50 mA by its dissipation rating. It has plus and minus V_{in} pins, ground pin, plus and minus V_{out} pins, balance adjust pin and two compensating capacitor pins needed only where external pass transistors are used.

Using the same concept, a simple-to-use fixed voltage DTVR, National Semiconductor plans to produce a series of such parts to be available in about 3 months. The four members of the series will be available in three different packages: the TO-100, the 14-pin DIP and a new one, a molded 14-pin DIP power package soldered to a plated-copper bar designed to fasten to a larger heat sink. This new package is rated at 8W at 25°C, derated at higher temperatures by 12mW/°C. The new devices will have all the usual goodies; internal current limit, over-temperature protection, built-in compensation, plus pins for optional current boosting with current limiting for the external device. Load capacitors are not needed at the outputs. The chip's output stage will be good for 100 mA each side. With the 14-pin DIP packages, three pins are internally tied together for each of the V_{in} connections to provide the option for using them shorted externally to get better heat transfer from the device's output stage. National's new parts are:

- LM125 fixed at +&− 15V.
- LM126 fixed at +&− 12V.
- LM127 fixed at +5V and −12V for MOS memories
- LM128 adjustable with two external resistors from + & − 12V to + & − 30V.

For specifications and applications, circle these numbers:

Motorola Semiconductor Products Div., P.O. Box 20912, 5005 E. McDowell Rd., Phoenix, AZ 85036 **RS No. 276**

Raytheon Semiconductor Div., 350 Ellis St., Mt. View, CA 94040 **RS No. 277**

Silicon General Inc., 7382 Bolsa Ave., Westminster, CA 92683 **RS No. 278**

National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051 **RS No. 279**

—JM

Electronic response system promotes student-teacher communications

An electronic student response system is helping to increase the efficiency of student-teacher communication at the University of Southern California School of Medicine. The system, recently installed in the Louis B. Mayer Medical Teaching Center, allows individual student participation and response which would otherwise be impossible in the large classroom environment of the 500 seat auditorium.

Questions are initiated at the teacher's console of the electronic student response system. The console then indicates how the class answered the question. It does this by percent correct and percent who selected each wrong answer.

Students use a pushbutton panel to select the right answer to questions chosen by the instructor. A flashing light on the panel tells the student if his response is correct.

As questions are presented by the instructor, a pushbutton device on the arm of 265 seats allows the students to pick one of five possible answers. The device immediately indicates to the student whether he is right or wrong, and indicates to the instructor the percentage of the class responding, and the percentage correct or incorrect for each possible answer.

An electronic scanner collects individual student responses and feeds them to a computer, which analyzes the data and then prints it out on a teletypewriter. This provides the instructor with a detailed analysis of question-by-question performance by individual students, and the class as a whole. Thus, the instructor can rapidly assess student understanding of materials presented and identify areas that need additional attention.

The new system represents a marked advantage over the traditional method of assessing student comprehension by giving quizzes, which have to be graded and then returned to the student—a tedious process entailing a long time-lapse between presentation of the material and the instructor's determining how the material has been assimilated.

As noted by Dr. Phil Manning, Professor of Medicine and Associate Dean of Postgraduate Medical Education at USC, "The new system will allow the USC faculty to organize problem-solving sessions with active participation in large groups. These activities have previously been restricted to small groups."

The $80,000 system was designed and installed by Instructional Industries, Inc., of Ballston Lake, NY. —*FE* □

Hewlett-Packard's HP-35 calculator has a brother. One for the financial market.

Buoyed by the fantastic success it has had with its Model 35 electronic calculator (sales have topped 50,000 units so far, worldwide, in the last 11 months according to president William Hewlett), Hewlett-Packard is introducing its twin brother, the Model 80. This one is aimed at the banking, real estate, accounting and finance markets.

Weighing only 9 oz, the Model 80 is designed to do virtually all financial calculations involving the relationship between time and money. Far from being capable of performing the four basic functions of addition, subtraction, multiplication and division, the HP-80 is preprogrammed to do 36 separate financial computations.

These calculations include bond yield and price, compound interest, mortgage payment and analysis, trend lines, rate-of-return analysis, accrued interest, discounted notes, true equivalent annual yield, annual percentage rate conversions, and mean and standard deviation. It is also a 200-year calendar.

Capable of performing 40 separate financial calculations, Hewlett-Packard's new HP-80 $395 calculator, designed as an outgrowth of the HP-35 scientific calculator, is directed at banking, real estate, accounting and finance market applications.

Whereas the HP-35 scientific calculator has one level of programming, the HP-80 has two. An entire program needed to solve a specific equation is executed, including the necessary subroutines, all with one keystroke.

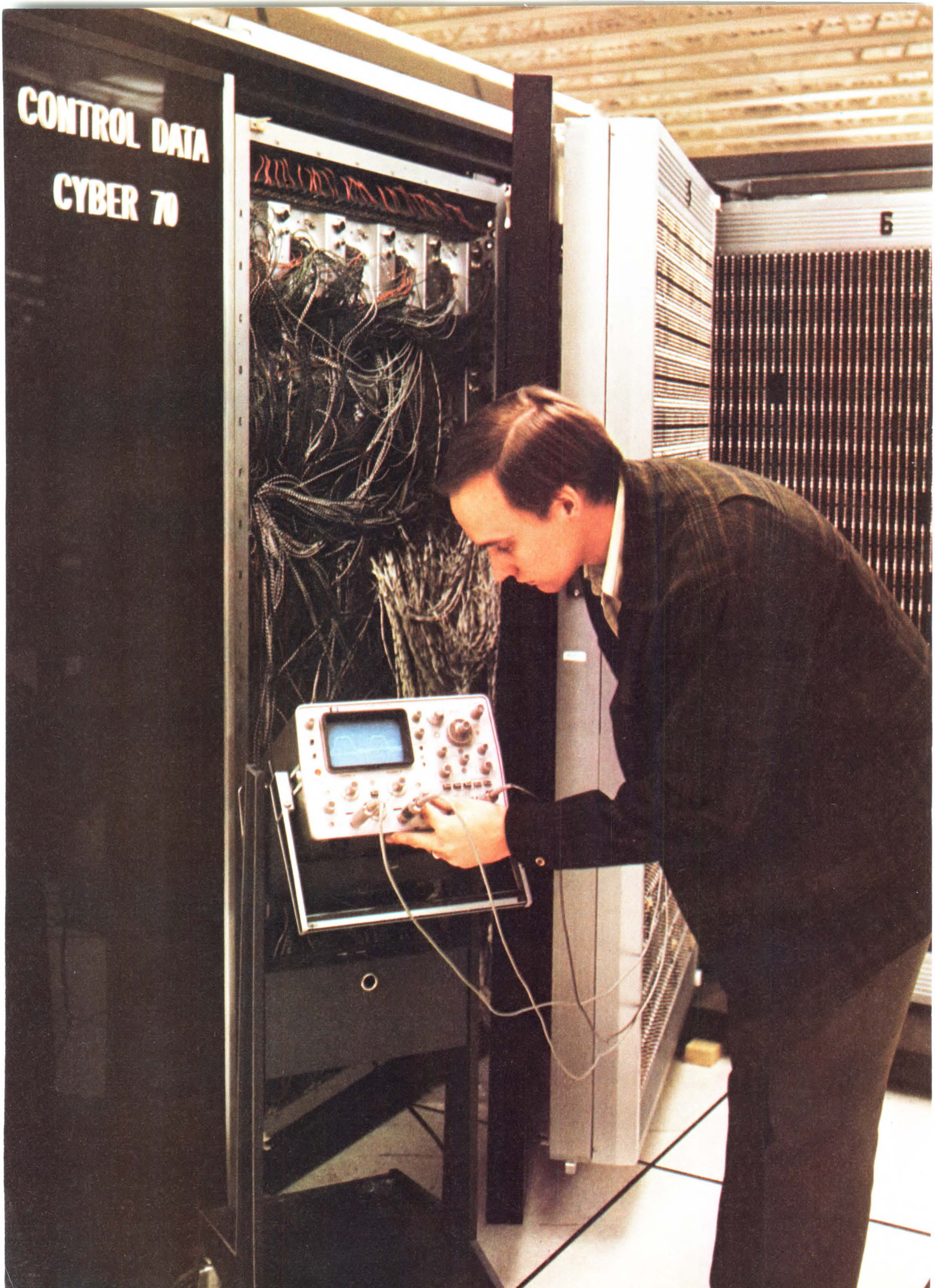
Four temporary memory registers used in the HP-80 are arranged in a stack, in the same way as in the HP-35 scientific calculator. Like the HP-35, the HP-80 uses reverse Polish (Lukaiewicz) notation. This scheme helps achieve the goal of packing a great deal of calculator power into a very small space.

The operational stack consists of four registers, X, Y, Z and T. The stack stores intermediate results and the calculator automatically recalls them from the stack when required for further processing. This eliminates the need for manual scratch notes or re-entry of intermediate answers. Only the contents of the X register are displayed on the 15-character 7-segment LED display.

The HP-80, just as the HP-35 uses specifically designed MOS/LSI circuits that utilizes a low-power, high-performance ion-implantation process. The HP-80 uses seven ROMs vs three for the HP-35. The four additional ROMs handle logic needed to solve the complex equations utilized.

Powered by rechargeable nickel-cadmium batteries with about five hours of operating time, the HP-80 can also operate from 115/230V, 50/60 Hz. An ac adapter-recharger is provided. Power dissipation is 500 mW for battery operation and it is 5W for ac power line operation.

Price of the new HP-80 is $395. —*RA* □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Analyze your total measurement needs, then ask both manufacturers to submit prices. On currently available models, you'll find that HP can save you money—lots of it in most cases. Check carefully on all aspects of cost and performance. Whether you are comparing real-time systems with or without delayed sweep, or sampling units, you'll find that HP still offers a cost/performance advantage.

Check Ease-of-Use.

Compare simplicity of controls, display size and error-prevention devices. Does the scope have useful, time-saving features, like selectable input impedance, variable-persistance storage and simplified sampling? Check writing speed; HP's new burn-resistant storage scopes are brighter than scopes have ever been, and write at a speed up to 400 cm/μsec. This means you no longer need to bury your head under a scope hood to view fast-risetime, low-rep rate signals.

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Compare calibration time needed for each manufacturer's unit. You'll find it takes less time with an HP scope. In fact, some companies bought HP scopes because of this one fact alone. You'll also discover that HP scopes are backed by video tapes which cut the time you spend training your calibration people.

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You owe it to yourself to make these comparisons before you choose your next scope. To help you compose the check list for the scope that meets your personal needs, send for our "No-Nonsense Guide to Oscilloscope Selection." Or, contact your local HP field engineer for a demonstration. Think twice and check before you choose. Hewlett-Packard, Palo Alto, California 94304. In Japan: Yokogawa – Hewlett-Packard, 1-59-1, Yoyogi, Shibuya-Ku, Tokyo 151, Japan. In Europe: HPSA, P.O. Box 85, CH-1217 Meyrin 2, Geneva, Switzerland.

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083/2

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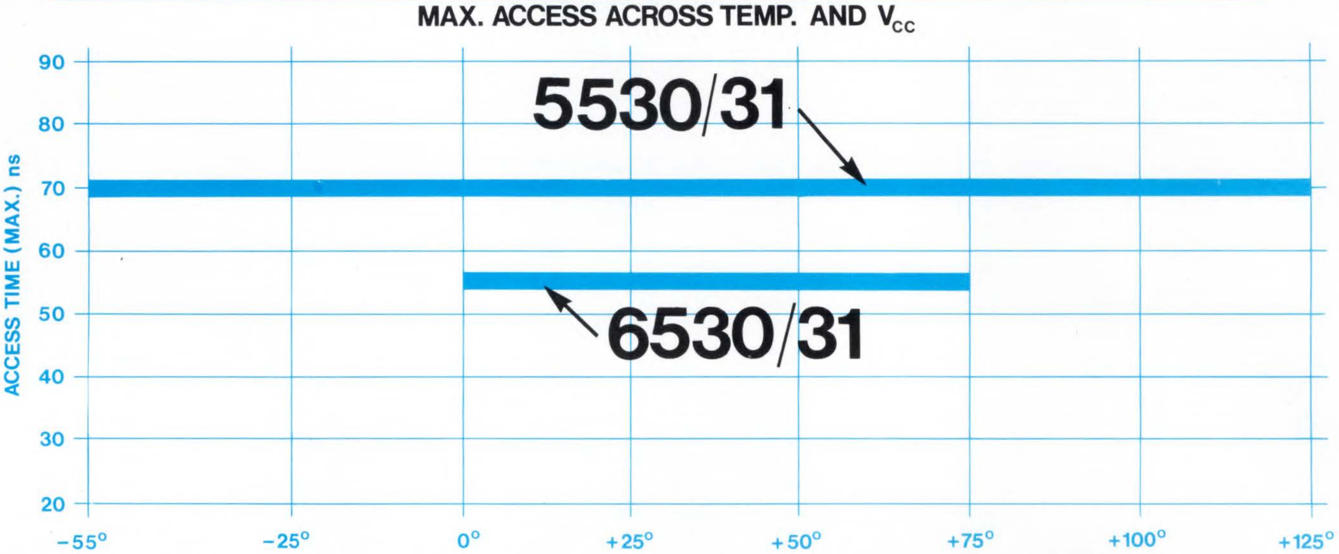

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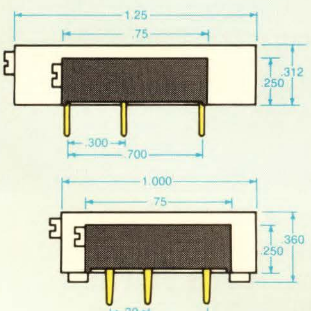

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Designers Roundtable

How users look at bench test equipment and its manufacturers.

Specs, servicing and design are hot topics as usual, but you may find some new light shed on old problems.

The problem of accurate communication is as old as man and has not yet been solved, even with the current technological explosion. The areas of science and engineering, which are noted for their precise definitions and measurement, still have their communication problems. This became apparent very early in our Designers Roundtable on bench test equipment when it was found that there is a need to define what we mean by bench test equipment and who is our user.

As engineers, we tend to think of test equipment primarily in the R&D situation; but as one of the participants pointed out, bench equipment is going to end up in a production manufacturing situation in many instances—in fact more times, probably in total volume, than it does in the R&D situation. Therefore, for our purposes we will define bench test equipment as the broad range of manually operated, stand-alone instruments that would be used in R&D or on the production line as stand-alone instruments, or built into manual and semiautomatic test systems.

Our user is either an electronics technician or a production technician for the most part, recognizing that engineers are also users and probably do most of the specifying for new instrument purchases.

Can you overcome specsmanship?

Anyone who has been involved in the process of specifying, buying and using bench test equipment knows that there is a communications problem relating to specifications. Most of the Roundtable participants have been through this process and therefore don't take specs at face value.

As Bob Chandos put it, "The wise engineer is beginning to understand specsmanship. He's beginning to understand that one manufacturer will state his voltmeter accuracy at a nominal temperature and then in small print—or maybe not at all—mention the errors that occur with temperature. He knows that this spec sounds better than the one that specifies worst-case conditions."

Not all specification problems are the result of questionable practices. Incomplete information also creates problems for the user. When talking about BDC outputs on instruments, Erich Laetsch commented, "I can only think of a couple of manufacturers that specify the interaction between the BCD output and the input. How much is the input common-mode rejection spec degraded by hooking something up to the BCD output? What's the noise isolation?"

While most agreed that a standard method of writing specs would be the most ideal method of solving the problem from the user's point of view, there was lack of agreement on the feasibility of this solution.

Taking the opposing position, Erich Laetsch said, "I don't think it's realistic for us to say spec sheets should be better. It's just not going to happen."

There were things, though, which the Roundtable thought manufacturers could reasonably do to help the engineer who's specifying equipment. For example, there could be "a consensus among manufacturers on how they are going to specify their equipment—a common terminology. If not that, at least, define in the literature the test method or process they used to generate the numbers when it deviates from the generally accepted means of defining the specification."—John Stallard.

"If the manufacturers cannot establish a commonality (in specifications), the next best thing is to supply application notes on how the piece of equipment is used. What does the equipment measure? How does it measure? What accuracy can you expect in a typical measurement situation?"—Charles Motzko. He also pointed out another advantage of application notes.

"Application notes in addition to spec sheets would make a lot of difference in whether or not people are really interested in a piece of equipment. A good example is in the scope market. How many engineers a year and a half or two years ago could use 300 MHz real time? Now everyone is crying for it. A couple of manufacturers really played it up and showed the engineer how he could find fault in his design by going faster real time. They developed the market."

Participants in the EDN Designer Roundtable on bench test equipment

Charles Motzko
marketing manager
Electro Rents
Burbank, CA
Electronic instrument rentals

Art Stapp
West Coast Field Editor
EDN Magazine
Los Angeles, CA

Erich Laetsch
Custom Electronic Design
Camarillo, CA
Custom instrumentation

Robert Chandos
vice president and technical dir.
Electro-Optical Industries
Santa Barbara, CA
Low-level instrumentation and IR equipment

Fred Franey
associate administrator
North American Rockwell
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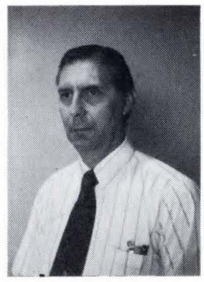
Liquid rocket engines



John Stallard
manager of metrology department
Collins Radio Co.
Newport Beach, CA
Communications products

What's an engineer to do?

Faced with the reality that things are the way they are today and probably won't change much in the near future, how can an engineer who is buying bench test equipment avoid the traps of specsmanship?

Erich Laetsch laid it in the lap of the engineer by saying, "He has got to learn to use the telephone. It strikes me as odd that very competent people involved in engineering development, knowing that data sheets are inadequate, will be trapped by them. It would be embarrassing to have an engineer tell me about a problem with a $5000 box he bought, show me the data sheet and say 'Look, they lied to me,' and find out that he didn't even call up the prime candidate for this box, or talk to the applications people about what he intends to do, and thus find out if it will be suitable."

John Stallard agreed and pointed out, "When there has been a real question whether the product was suitable or not, I've contacted the manufacturer. They have been very cooperative in providing an evaluation unit. I think the larger manufacturers do a fair job in this area. When you get to the small manufacturer, he may not be in a position to do it, even though he may have the best box."

Small companies, having shorter paths of communication, have an advantage though, as pointed out by Bob Chandos. "Frequently with a small company, they'll let you talk to the guy who designed the instrument. He may frankly tell you its weak points, if it has any, and he'll tell you what's wrong with the specsmanship in the field because he may have spent a couple of weeks looking at his competitors." Bob Chandos also noted that there are potential pitfalls in this approach. "You may never reach the right man. Also, on a phone call, a man is not committed to what he's promising. You may send a purchase order for an instrument that you were told meets certain specs, but all he's really committed to deliver is a box that meets the specs on his latest data sheet."

Obviously, it's easy to stir up controversy on the subject of specifications, and everyone seems to have an opinion on the subject. Being aware of this, EDN reviewed the results of a marketing survey conducted by Interstate Electronics Corp.

In the portion we reviewed, about 15% of the engineers who responded with complaints of one kind or another complained about specs, even though the word was not mentioned in the questionnaire. An even higher percentage had complaints about data sheets in general.

Time is the essence of servicing

If you could distill the Roundtable discussion on the subject of servicing, you would probably end up with a statement like this: "I need to have it done faster." This was the key point throughout the discussion which touched on warranty service, repair after warranty and routine calibration.

Quality problems were also mentioned, and it was surprising to hear this comment from Charles Motzko. "Every major manufacturer, on their first production run, has from 5% to 25% incoming inspection failures in my experience. These are instruments that completely fail to work upon arrival from the factory, and they have QC stamps on them. I can't think of one manufacturer that I deal with—and I deal with 168—that has a reasonable failure rate of 1 or 2%. I think the buyer of a piece of equipment expects it to be productive upon receipt at his dock."

Bob Chandos claimed the percentages were even higher in his experience, but he was hesitant to fault manufacturers too much. He felt it was not too surprising considering the complexity of some test equipment and pointed to complex consumer products like color TV sets which he claimed have higher failure rates. Summarizing his position, Bob stated, "When there is a lack of quality, manufacturers make up for it by bending over backward to replace a defective unit."

While there was general praise for the way manufacturers support users when a new instrument is found to be defective, there was dissatisfaction in the way they handle replacement parts. This is where the time element came in. The comments went like this: "It costs money for downtime, and if you don't have a backup, you have a problem."—Fred Franey.

"I have only one objection on repair. That's the turnaround time involved. I think manufacturers should track their field failures better than they're doing now and stock for those problems they can anticipate."—Charles Motzko.

"We had a major program down just the other day because of a one-of-a-kind instrument. We needed a particular high-frequency transistor that was unmarked. The local instrument vendor had none in stock, but we finally coerced him into telling us who the manufacturer was. He was also going to deliver too late, and it finally took a phone call to the president of the company. When we explained to him why we needed one transistor, we finally got it."—John Stallard.

"It seems to me that what we need from the manufacturers is an inventory of spare parts and someone you can get on the phone who knows what's going on. They when you have a piece of equipment down, you can get on the phone, say 'here is my problem, I need the parts, what are they?' I want to be able to find a second source, if necessary, or I want to have a special part put on the plane right now. I'll fix the instrument myself."—Erich Laetsch.

"You don't want the response, 'I can't do it.' If a fellow says to me I can't get you the part within five days unless you can pay $25 extra, he's going to get a positive response, 'do it' because I'm already spending money in downtime, purchase orders, phone calls and a special truck to the airport. I'd like that person on the other end of the phone to recognize that I've got a real problem."—John Stallard.

"A positive solution to the problem would be for the major manufacturers to set up an expedite service on parts where you pay a premium for them. We're not asking them to do it for nothing. We realize the economics of the situation. But, for a premium price, you should be able to get a part immediately, or within a reasonable length of time."—Charles Motzko.

"Another problem is when a manufacturer puts out a number of units of a particular instrument and then stops making them. We have some equipment that we can't duplicate, and the unfortunate result is that we can't buy parts for some of them. Before you know it, you're tearing down one unit to repair another."—Fred Franey.

New thoughts on calibration

The Roundtable participants were equally concerned with the time and expense involved in instrument calibration. Fred Franey got to the heart of the problem when he said, "There is generally more money spent on calibration during the life of an instrument than on the initial purchase price."

Almost everyone agreed with this statement, and there were several areas in which it was felt that manufacturers could help. And it wouldn't necessarily have to be in design alone. Bob Chandos expressed the opinion that "In most modern instrumentation, the calibration interval could be extended from 90 days to 6 months or a year. A lot of government contracts say that calibration will be done 'at manufacturers' specified calibration intervals.' If manufacturers took a good hard look at their real required calibration intervals, they might cut calibration costs in half, simply by reducing the calibration frequency."

Charles Motzko felt that manufacturers could have both a detailed and short-form calibration procedure in their manuals. "The short form could check major parameters. For example, if everything in a particular divider string is good, why go in and tweak it. Everyone tends to be too detailed—going by the book—for calibration."

Some comments were directed toward design and how that could be improved from the calibration standpoint. Most participants agreed with this statement by John Stallard. "The one major area from the service/calibration standpoint that would be most beneficial for those of us providing that service would be the ability to prove the instrument to be within the spec or not, without having to pull the cover off all the time. We need to have a built in ability to put in the inputs required and to have the necessary monitoring points brought out to a convenient location."

The point was stressed that this didn't mean bringing the calibration controls out—just the test points—so that a technician could determine whether or not an instrument needed adjustment before starting to disassemble.

Taking this subject of testing a step further, Erich Laetsch made the comment, "In almost any piece of equipment, a simple self-test function is possible using internally developed calibration voltages that allow you to flip a switch to tell you, yes, it works or no, it doesn't."

While everyone agreed that this is a desirable thing to have, it was recognized that manufacturers have to charge for these conveniences. This naturally led to the consideration of cost of ownership. The Roundtable participants were acutely aware that this is different from cost of purchase.

Bob Chandos stated, "I'm willing to pay a 20% premium when I buy to assure myself that the equipment is not going to be offline for more than six hours or so. This is generally true of high priced equipment. If you're talking about DVMs, even in the couple-of-thousand-dollar range, I feel that if I need a voltmeter desperately, I can rent one. In that case, I would probably not pay for self-test."

A statement by Charles Motzko seemed to summarize the general feeling on this subject. "More people are asking, what are the anticipated costs of maintenance? What is the anticipated downtime? What are the anticipated calibration costs? When they start lumping these things together, they may buy an $8000 box rather than the $5000 box."

Less miniaturization, more information

Most of the problems the participants encountered in actual use of test equipment centered around the interface between the operator and the instrument—the control panel.

Miniaturization is not always appreciated, as indicated by Charles Motzko's comment, "Human fingers don't shrink with technology. When you use some instruments day after day, they become a pain to use if the controls are too small."

Use of alternatives to rotary switches and placement of infrequently used jacks on the rear panel were some of the suggestions given to avoid overcrowded control panels.

Front-panel labeling practices received their share of knocks too. To be more specific, it was the lack of labeling that drew most complaints.

John Stallard pointed out some problems he has had with similar voltmeters that have different dB reference points. "When I see zero dB on a panel meter, I have a definite opinion where zero dB is. If the manufacturer deviates from standard practice, it ought to appear in big red letters."

Other comments along these lines included: "More labeling on control panels would be appropriate. For example, DVMs that have range controls that imply the ability to go up to 1000V, when in reality the 1000V button is limited to 600V. It would be nice if that was noted somewhere other than on the back page of the instruction manual."—Erich Laetsch.

"Input and output impedances should be plainly marked."—John Stallard.

Lack of overload indicators and indicators that were not conspicuous enough were other hot topics. Bob Chandos expressed the opinion that "An operator should always be informed by the instrument when he is doing something invalid or making a measurement that is invalid."

Pointing out specific problems, Erich Laetsch said, "On signal processing equipment, you may be generating internal harmonics because you're 50% overloaded. Without overload indicators, you don't know it."

When asked again about increased costs as a result of having more indicators, Charles Motzko replied, "I think when you start looking at the cost tradeoffs between engineering time and initial cost of the instrument, most people would be more than willing to pay for the increased initial cost."

The only electronic design problem to draw much fire was in the area of BCD outputs. This was primarily centered around the lack of buffering. Erich Laetsch stated, "Panel meters are a notable example of this problem, and I think all of the moderately expensive digital test equipment falls into the same category. Instrffments under $1000 are generally not buffered, and if not, they are worse than worthless—they're dangerous. You'll burn out your piece of equipment if you misuse it, and you're bound to do that."

As Bob Chandos pointed out, "Sometimes

people may not realize how bad they are. For example, low-cost digital panel meters only have the correct value for the few milliseconds that the display is strobed. For that reason they (BCD outputs) are essentially useless." He added, "Most of the engineers who have done any digital interfacing recently are probably aware of the problem of unbuffered outputs. If they plan to use outputs, they certainly give some thought to ordering buffered outputs."

Some of the other problems users complained about were digital readouts that imply an accuracy greater than that specified (for example, a 5-digit readout of ohms when the accuracy is 1%) and lack of standardization on input connectors and power cords.

There's positive feedback too

It's always easy in a session like this to dwell on the negative and give the impression that the manufacturer is a bad guy. However, this was not the atmosphere that prevailed at the Roundtable. The participants had many positive comments about instrument manufacturers. They felt that the cost/performance ratio is getting better all the time and that manufacturers unanimously stand behind their products and try to solve problems, even if it does result in unwanted delays.

Several specific trends were mentioned that were considered good new developments. Speaking on this subject, Bob Chandos said, "There's a trend now that I like to see, and that is a lot of self-test built into complex instrumentation. A beautiful case in point is some of the latest computing counters that totally self-test. When there is a problem, the instrument finds it itself in minutes."

There was considerable comment on bussing systems too; particularly, the ASCII bus system. Charles Motzko, an obvious supporter of this trend, said, "I think this is the most fantastic thing to come along in test equipment since the standard cell." Enlarging on the subject, he went on to say, "I think manufacturers have to design this capability into present and future instruments for those people that require it. Let's at least have a field modification so you can go on ASCII bus or some other method of semiautomated control. I think the ASCII system appeals to everyone because you can either run the instrument stand alone or ASCII and there is absolutely no software involved." □

EDN wishes to thank IEC for the marketing survey information that they made available.

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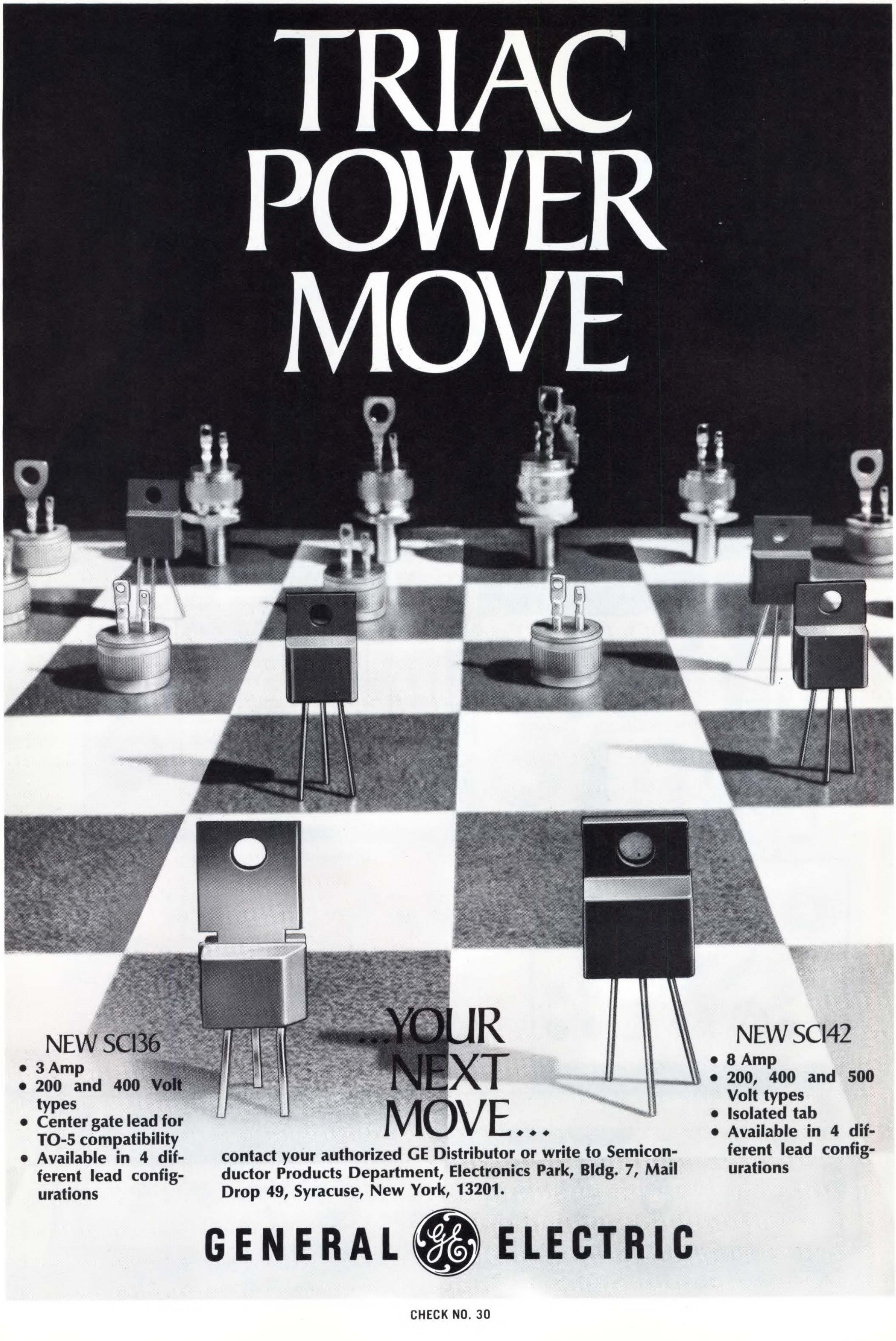
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EDN Design Course
CMOS—Part V

CMOS gates in linear applications: the results are surprisingly good.

Bill Furlow, Associate Editor

A discrete MOS/FET, as you know, is basically a linear device. Since CMOS gates, as shown in **Fig. 1**, are groupings of two or more p-channel and n-channel, enhancement-mode MOS/FETs on a monolithic substrate, they too would be expected to have some range of linear operation. In fact, they have.

The transfer characteristics of a 4007 inverter, as shown in **Fig. 2**, include a rather wide range of linear response. An inverter pair can be biased to operate within that region, roughly 25 to 75% of the supply voltage, as a reasonably linear amplifier.

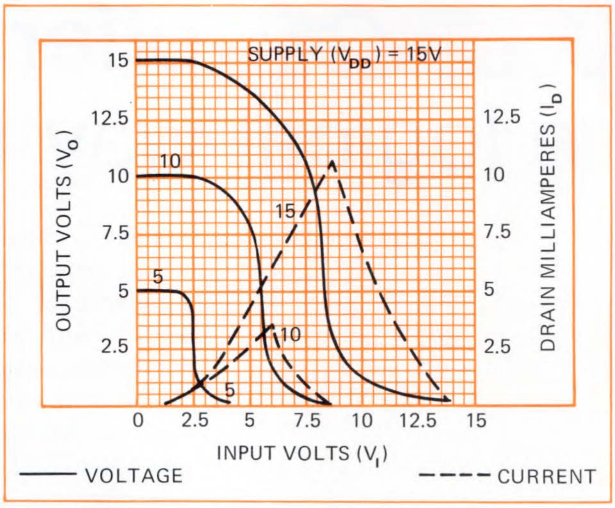

Fig. 2—Transfer characteristics of a 4007 gate show an area of linear operation from approximately 25 to 75% of the supply voltage. Operation in this region is not desirable for purely digital operation because power consumption is increased. However, the ability to use one IC family for digital and linear operation is obviously a strong point for CMOS.

Some simple amplifiers

Two methods for the linear biasing of one of the complementary pairs of FETs in a 4007 are shown in **Fig. 3**.

Biasing resistor, R_f, in **Fig. 3** is connected between the gate and drain terminals. The output, then, is biased midway between V_{DD} and V_{SS} during steady-state operation. A positive-going input will increase the resistance of the p-channel and reduce the resistance of the n-channel device, driving the output voltage toward V_{SS}, or ground in this case. Conversely, when the input signal swings negative, the n-channel resistance will increase; the p-channel resistance will decrease, and the output will swing toward V_{DD}, the positive supply voltage. That's all that's required to make a simple, inverting linear amplifier from a CMOS gate. R_f is commonly set at about 22 MΩ for the correct feedback ratio assuming a very high input-signal source impedance. The addition of an ac bypass capacitor, C_2, in **Fig. 3b**, makes the circuit adaptable for use in designs where the feedback of ac signals is not desirable.

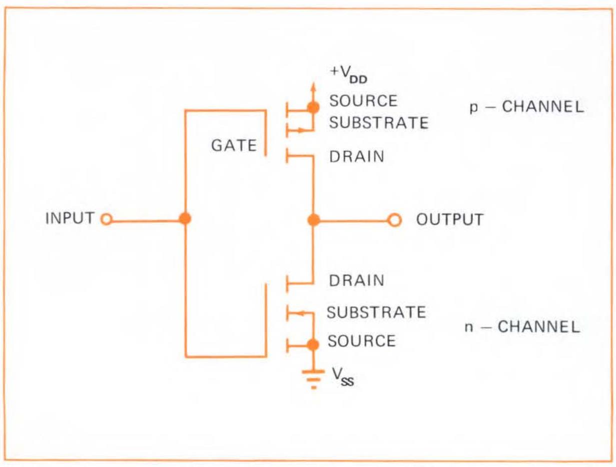

Fig. 1—Basic complementary inverter in a 4007 gate consists of 2 enhancement-mode MOS/FETs. The basically linear characteristics of these FETs has been partially overcome by using p-channel and n-channel devices in opposition, but linear operation is still possible.

Table I lists the performance parameters for the amplifier circuits in **Fig. 3**. As you can see, the power consumption, especially at the lower voltages, is extremely low.

Post amplifiers for op amps

A 4007 CMOS gate can be used for simple and

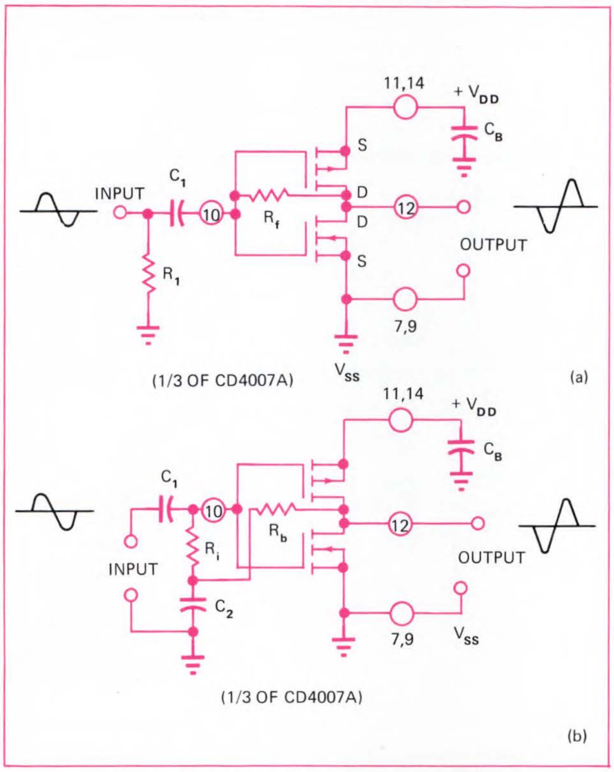

Fig. 3—Two methods of biasing a CMOS pair for linear operation are shown here. In the top circuit (**a**), the feedback resistor will hold the output midway between the supply voltage and ground during steady-state conditions. In the lower circuit (**b**), the ac feedback component has been eliminated through C_2.

convenient post amplifiers in conjunction with op amps. **Fig. 4** shows a single inverter pair used in conjunction with an operational transconductance amplifier (OTA) of the CA3080 type. The gain of the circuit operating in the open-loop mode, **Fig. 4a**, has a gain of $\approx$130 dB and a current handling capability of 6 mA. Slew rate for this combination OTA/CMOS amplifier is about 65 V/μsec. When compensated for operation as a unity-gain voltage follower, as in **Fig. 4b**, the slew rate is 1 V/μsec.

By using all three of the inverter pairs contained in a single 4007, the two-stage post amplifier shown in **Fig. 5a** maintains the 65 V/μsec slew rate of the single-stage, open-loop post amp, but achieves a gain of$\approx$160 dB. When used in the unity-gain, closed-loop mode shown in **Fig. 5b**, the 2-stage amplifier is still rated at 1 V/μsec.

TABLE I
TYPICAL CMOS AMPLIFIER PERFORMANCE
(For the circuits shown in Fig. 3)

Supply Voltage	Drain Current	Gain	Bandwidth (−3dB)
15V	6mA	29dB	1 MHz
10V	2mA	32dB	800 kHz
5V	150 μA	40dB	100 kHz
3V	400 nA	50dB	400 Hz

A single-supply amplifier

The voltage follower amplifier shown in **Fig. 6** uses two 4007 packages and one CA3083, a transistor array. It requires only a +15V supply and interfaces well with single-supply D/A converters or, for that matter, any +15V CMOS system design. A zener regulated leg provides bias for a 400-μA p-channel current source feeding the input stage. This input stage is terminated with an NPN current mirror. Voltage offset is nulled with a 10-kΩ, 10-turn balance pot. Second-stage current level is established by R_2. The CMOS inverter forms the final stage and is terminated with a 2-kΩ load, a typical value for monolithic op amps. Gain for this circuit is $\approx$75 dB and bandwidth is 60 kHz. Slew rate is $\approx$30 V/μsec and settling time is a rather long 2 μsec.

Micropower comparators with CMOS

If you are using comparators for A/D conversion in a CMOS logic system, the parts cost for the circuit shown in **Fig. 7** can be well worth the extra investment. The OTA and CMOS inverter may cost more than a standard comparator, say one of the 710 type,

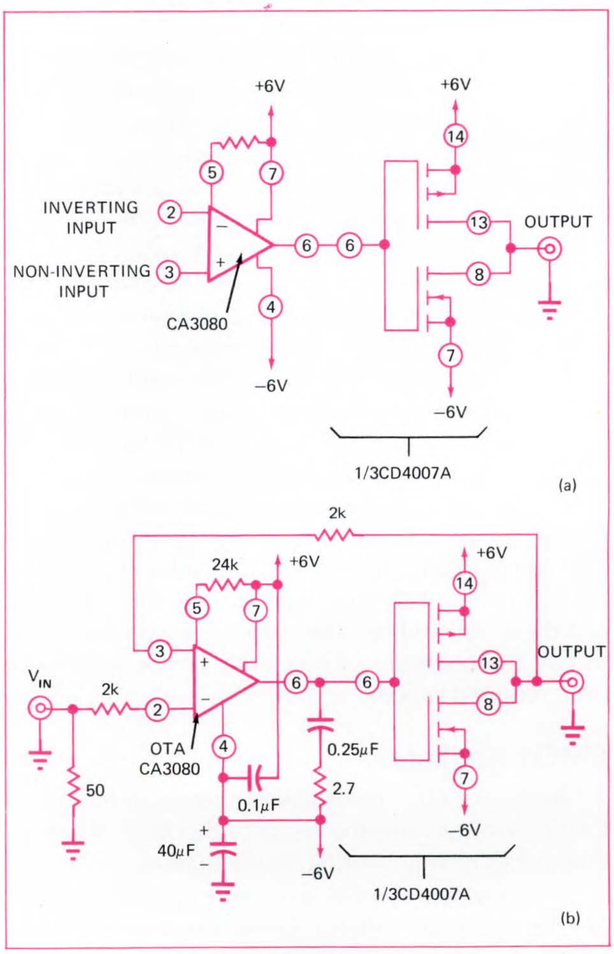

Fig. 4—OTA driving CMOS amplifier in the open-loop (**a**) and closed-loop (**b**) modes. Open-loop CMOS provides $\approx$30-dB gain, and the OTAs $\approx$100 dB. More stages of the 4007 can be paralleled to provide greater current output.

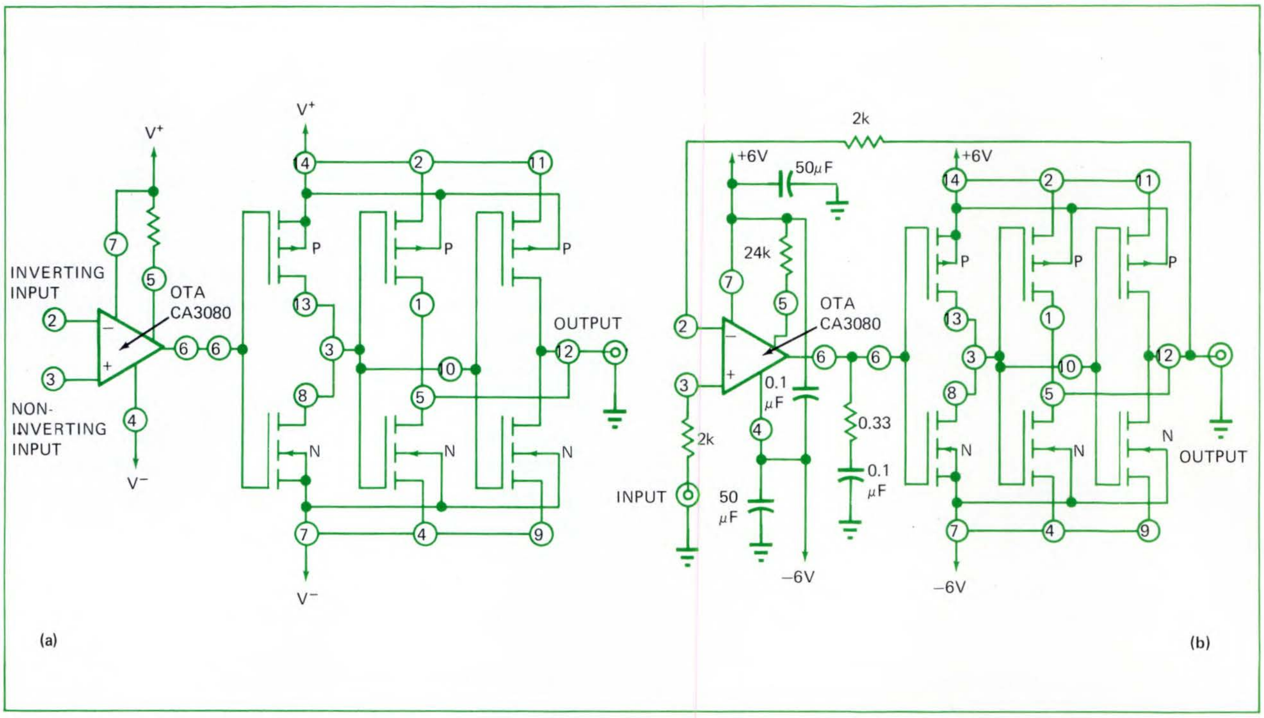

Fig. 5 – 2-stage CMOS amplifiers are shown in both open-loop mode (**a**) providing 160-dB gain, and closed-loop mode (**b**) providing unity gain. Paralleled gates in the second stage provide increased current source and sink capability.

but power consumption will be considerably reduced. Systems power levels were probably important if you chose CMOS for your logic design, so don't blow it in your choice of comparators. A 710 comparator consumes 90-150 mW of power, but the OTA/CMOS comparator consumes only 420 μW when strobed ON, and only 10 μW when OFF. Response time, however, is fairly slow at 8 μsec. By suitably biasing the OTA, the circuit response time to a differential-input signal can be reduced to 150 nsec. Power consumption soars to 21 mW—still not bad.

The differential amplifier input common-mode range for this circuit is −1 to +10.5V, and the circuit will toggle on input signals as small as 5 μV.

Voltage gain of the micropower comparator is about 130 dB, compared to a range of 33 dB for the 710 types. In all fairness, a 710 or related comparator will exhibit response times of less than 40 nsec, and there will still be times when you will be forced to pay the premium of increased power to achieve such required speeds.

CMOS oscillators

Quartz-crystal micropower oscillators using CMOS inverters are the heart of the new "Quartz" timepieces now appearing on the market.

In wristwatch circuits, size and operating power are the two main criteria. Designing a quartz wristwatch is not an engineering feat to be attempted with standard CMOS building blocks, so it doesn't fall into the main objective of this course. Most CMOS manufacturers have semi-custom CMOS circuits designed for the wristwatch industry, and their spec sheets and application notes will take you as deeply into the subject as you care to go. Two that we have seen are "Quartz Timepiece Components," an engineering report from Motorola, and "Timekeeping Advances Through COS/MOS Technology," app note ICAN-6086 from RCA.

Since the circuitry developed for wristwatches is available and may be of some use to you, the Motorola system is shown in **Fig. 8**. A typical oscillator operating from a 279.611-kHz "DT" cut quartz-crystal oscillator is shown in **Fig. 9**. It may be operated at supply voltages from 5 to 15V when using a 4007 inverter, and from 2.5 to 5V with the TA5987 (a developmental, low-voltage equivalent of the CD4007A). The values of components used apply only to operation with the 279.611-kHz crystal. These CMOS timing circuits lend themselves very well to practically any portable or mobile timing applications you can think of, including automotive. If you are planning an automotive design, the simple transient protection circuit shown in **Fig. 10** is highly recommended. The value of R will depend upon the minimum operating voltage and maximum operating current of your particular system. CMOS oscillators operating at less than 12V and at frequencies below 3 MHz typically draw on the order of 0.2 to 2.0 mA.

CMOS phase locked loops

Now that micropower PLLs such as the 4046 are appearing on the scene, designs of signal processing and conditioning, FM, FSK (frequency shift keying)

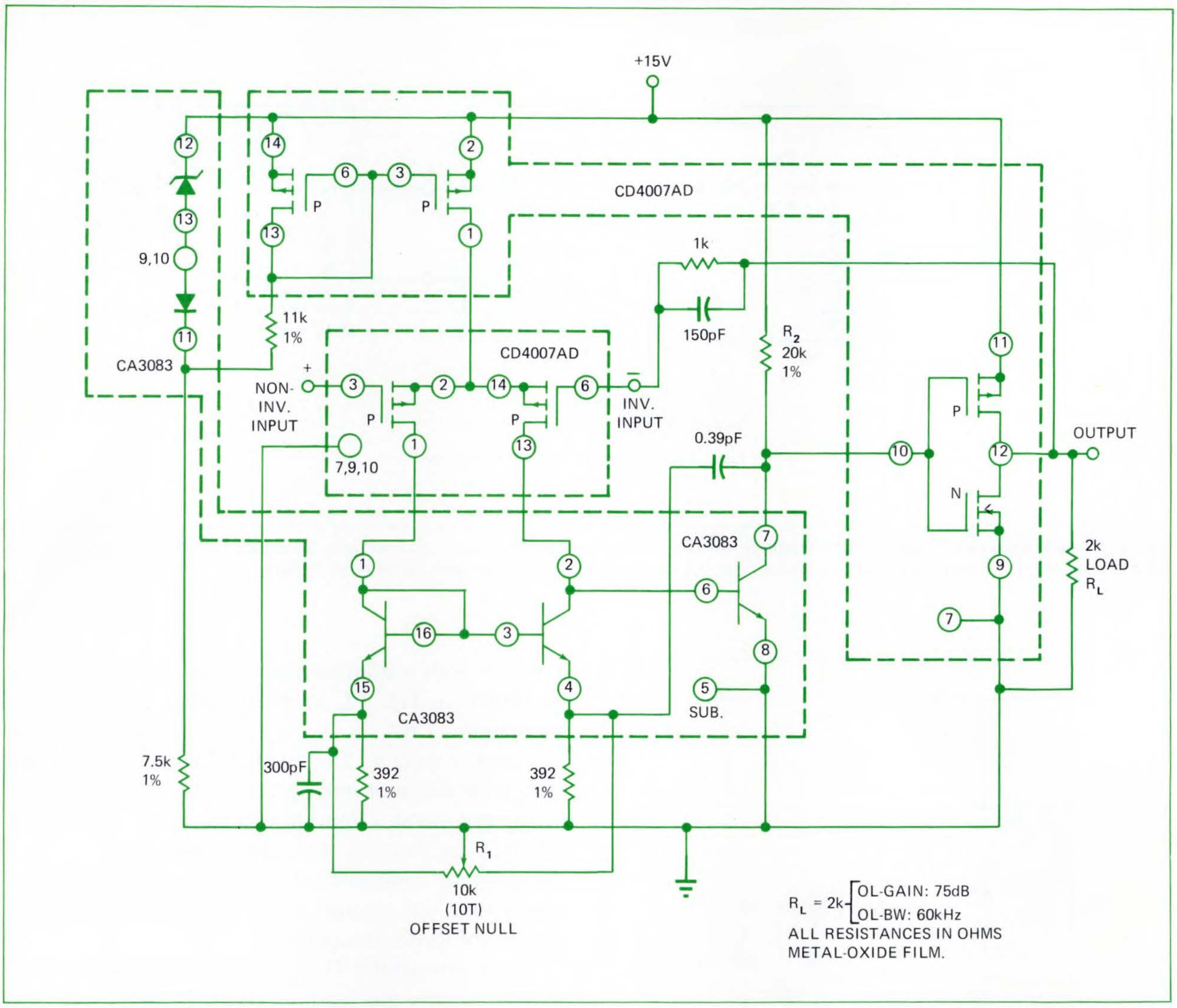

Fig. 6—Combination CMOS/bipolar voltage follower amp can be driven to within 1 mV of ground. Voltage gain is determined by the selected value of R_1.

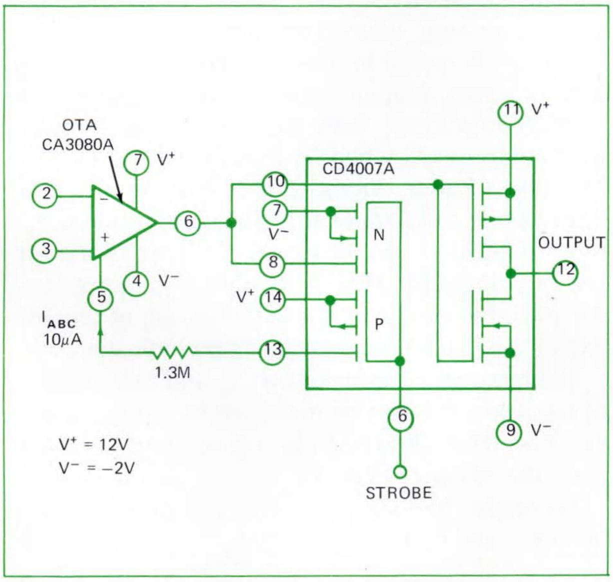

Fig. 7—Micropower comparators using OTAs and CMOS have a quiescent power consumption of a mere 10 μW. Even when strobed ON, power dissipation is only 420 μW.

and tone decoding and frequency synthesis will benefit greatly from the size and power reductions afforded. As shown in **Fig. 11**, the 4046 contains a linear VCO and two phase comparators. Typical power consumption is 600 μW at 10-kHz operating frequency with a 6V supply.

The PLL offers the choice of two phase comparators, and a 5.4V zener is provided for supply regulation where required. The VCO section requires one external capacitor, C_1, and one or two external resistors, R_1 and R_2. The R_1-C_1 combination determines the frequency range of the VCO, and resistor R_2 enables the VCO to have a frequency offset where needed.

The input impedance of $10^{12}\Omega$ simplifes designs of low-pass filters by permitting designers a wide choice of resistor/capacitor ratios. To avoid loading the low-pass filter, the output of the source follower is available at the Demodulater Out terminal, pin 10. When this output is used, a load resistor, R_s, of

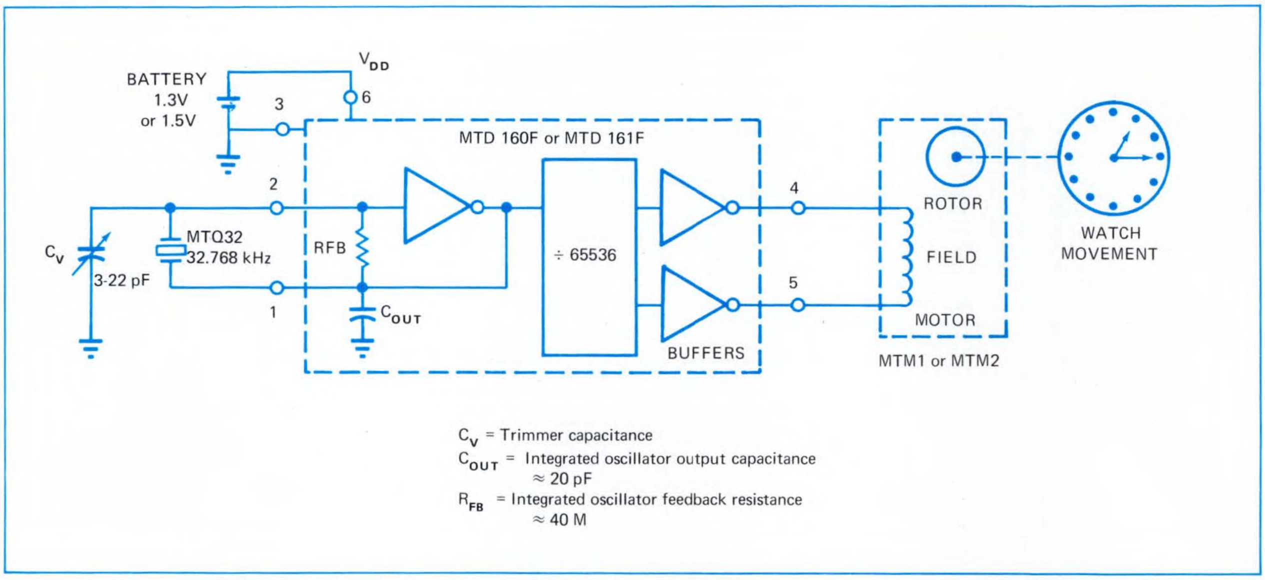

Fig. 8—Quartz wristwatch system from Motorola uses a 32.768-kHz quartz crystal, 2 capacitors, a custom CMOS chip and a stepper motor. The MTD160 circuit contains a 3-inverter oscillator, 16 counting flip-flops and motor drive buffers.

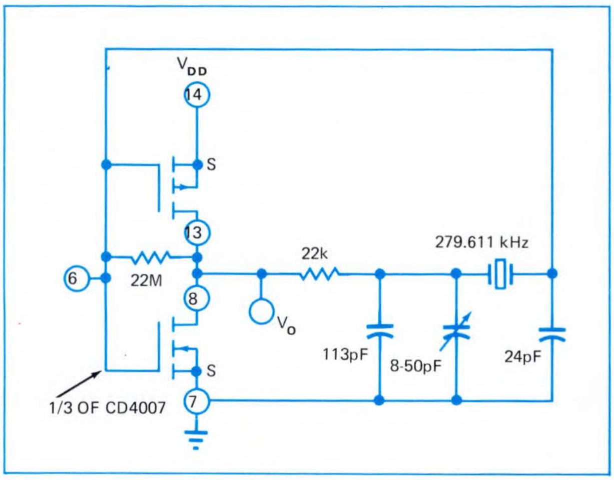

Fig. 9—Crystal oscillator using 4007 CMOS inverter is designed for operation at 279.611 kHz and provides a stability of 4.3 ppm, not including temperature variations.

10 kΩ or more should be connected from pin 10 to ground. When not being used, pin 10 should be left floating.

The VCO can be connected either directly or through frequency dividers to the input of the comparators. A logic ZERO at the Inhibit input, pin 5, will enable the VCO and its input source follower, while a logic ONE disables both circuits in order to conserve standby power.

The phase comparators can be direct coupled if the input-signal swings meet the standard CMOS input-level requirements. For voltage swings less than those levels, but greater than 50 mV p-p, the signal must be capacitively coupled to the Signal In amplifier through pin 14.

The first phase comparator is an exclusive-OR network with a triangular phase vs. output response as shown in **Fig. 12**. With no signal on the input, comparator I has an average output equal to 1/2 the V_{DD} supply voltage. The external low-pass filter at the comparator output will set the VCO input to the average comparator output voltage. This causes the VCO to oscillate at the center frequency, f_o. PLLs using phase comparator I can lock on input frequencies within its capture range and also on the harmonics of those frequencies.

Phase comparator II is an edge controlled memory that compares the leading edges of the signal and comparator input signals. It provides continuous control of the VCO input voltage, again through the low-pass filter, to maintain frequency and phase equality between the two signals. When no input signal is present, phase comparator II sets the VCO to idle at its lowest frequency. This is accomplished with a 3-state output which automatically goes to its high-impedance state, decoupling the comparator from the VCO when no input signal is available. The Phase-Pulses output, pin 1, will be at a logic ZERO while comparator II is sinking or sourcing current to the VCO, and at a logic ONE when the output of comparator II is in its high-impedance state. Among other uses, this Phase-Pulses output provides a readily available signal acquisition indicator.

The frequency-capture range, f_c, and lock-in speed of the 4046 PLL can be increased by using a 2-pole low-pass filter, shown in **Fig. 13**, to replace the low-pass filter shown in **Fig. 11**.

Maximum frequency of the VCO in the 4046 is 500 kHz, and its linearity (with V_{IN} = 5 ±2.5V) is 1%.

Analog signal switching

CMOS transmission gates are used in quite a few

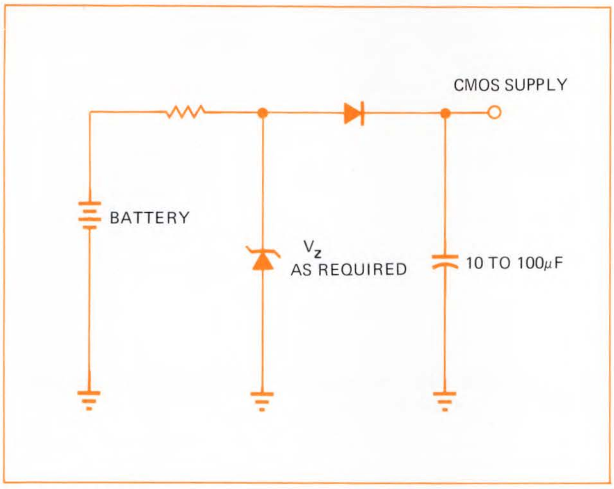

Fig. 10—Simple transient-protection circuit is recommended for use in automotive and other high-noise systems.

places in the more complex CMOS MSI devices. Normally they are used for digital data routing chores, but they also provide the 3-state output capability found in many CMOS gates. In the world of analog switching and multiplexing, CMOS transmission gates have a lot to offer. **Fig. 14** is a schematic of the 4016 quad-bilateral switch, which consists of four CMOS control swtiches and four CMOS signal switches. The signal switches are paralleled n- and p-channel MOS/FETs, and despite the normal labeling of terminals for "in" and out", they are truly bilateral or bidirectional. When switched ON, they appear as a nearly pure resistance, typically 300Ω, in the signal path. Unlike bipolar switches, there is no voltage offset to contend with when using CMOS switches.

When you use CMOS transmission gates of the 4016 type for analog-signal switching, there are two important things to remember: the positive peak of the largest signal you anticipate switching must not exceed the voltage of the positive supply V_{DD}; similarly, the most negative peak of that signal must not be more negative than the negative supply, V_{SS}. This, by definition, limits you to 15V p-p when using the standard 4000 Series CMOS devices.

Signal response of these switches is flat to about 6 MHz, with the −3-dB points occurring between 25

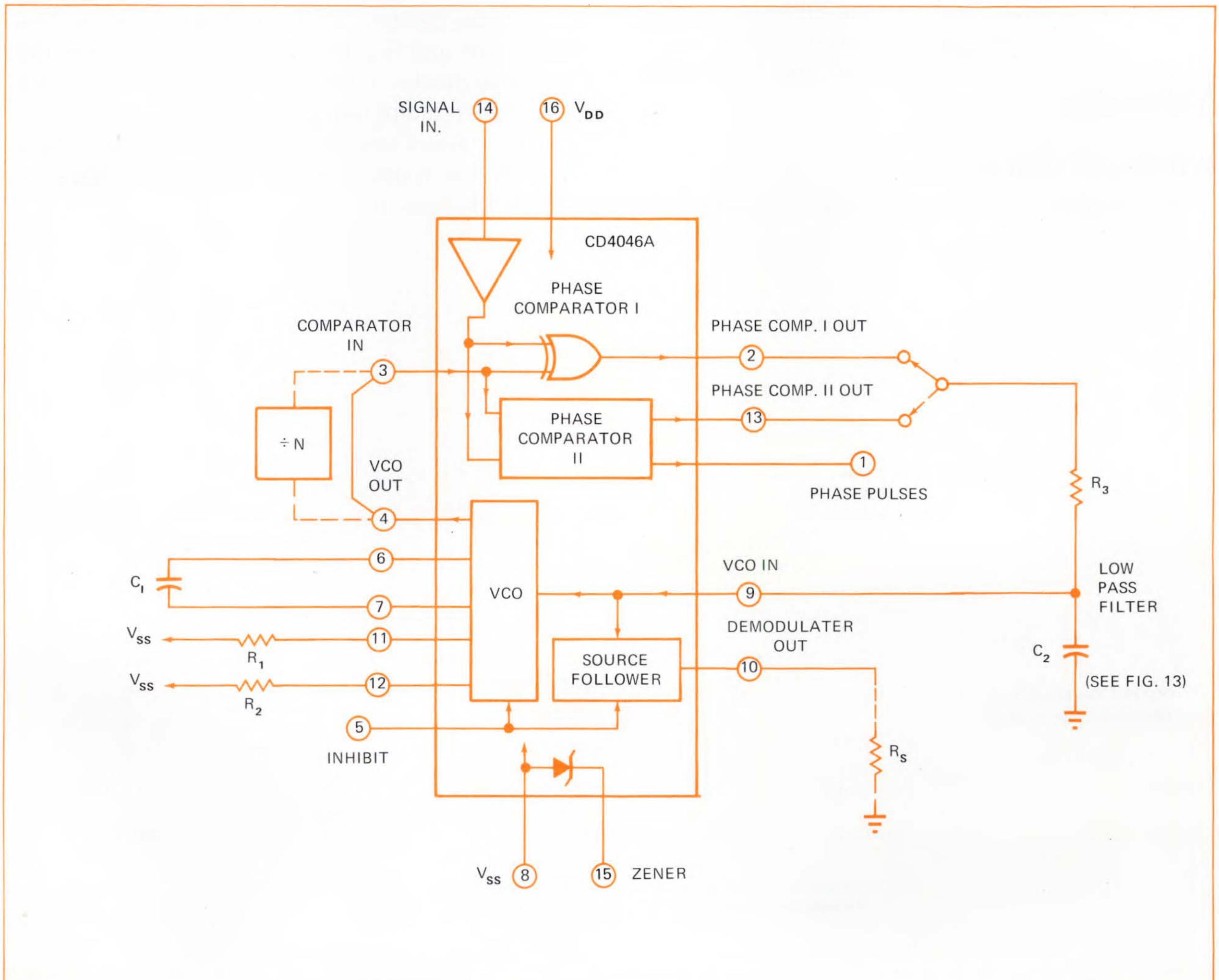

Fig. 11—CMOS phase locked loop operates on 600 μW. The availability of such complex circuits in a single 16-pin DIP or flat-pack is one of the reasons that the CMOS logic families have gained such a strong foothold.

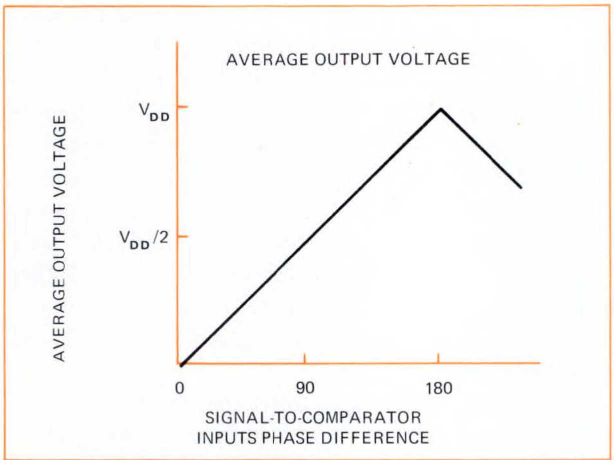

Fig. 12—PLL's exclusive-OR comparator output shows a linear voltage output signal in direct relation to phase error.

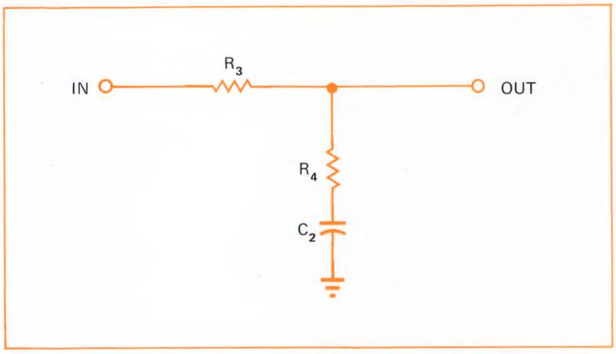

Fig. 13—2-pole filter increases lock-in speed and frequency-capture range for the 4046 PLL.

and 40 MHz depending on the load impedance. Distortion of a 1-kHz sine wave of 5V p-p when operating from ±7.5V dc supplies is 0.2%. Distortion of the same input signal is 0.4% when operating from ±5V dc supplies and 3.0% when operating from ±25V dc supplies.

Other applications in which the bilateral switches will be especially useful are for resistor-ladder switching in D/A conversion, sample-and-hold circuits and level detectors.

Will linear CMOS grow?

The savings of parts inventory expenses alone may force some designers of CMOS digital systems to use the same devices for linear applications whenever possible. The feature that got digital CMOS off the ground in the first place—ultra low power—will interest many linear designers. There really isn't much to prevent the burgeoning of linear applications for CMOS. As soon as enough designers show enough interest, the manufacturers of CMOS devices will analyze and spec the linear characteristics of those devices. No doubt the ubiquitous 4007 will be first and find the widest application because there is so much internal accessibility to that device. Later, other multiple-input gates will probably be spec'd for linear service because some bright design engineer has found a linear application that's just too good to pass up. ☐

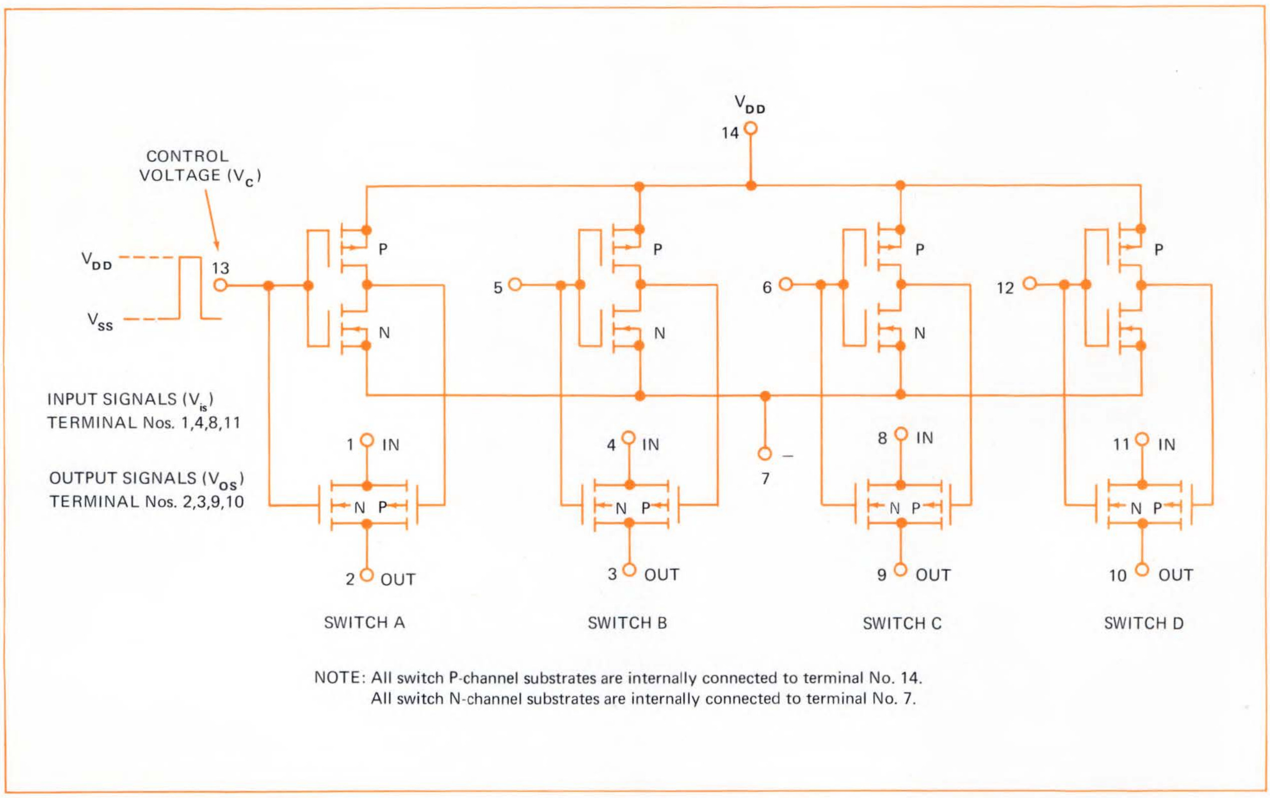

Fig. 14—CMOS bilateral switches, like the 4016 shown here, can switch analog signals of up to 15V p-p at frequencies in excess of 10 MHz.

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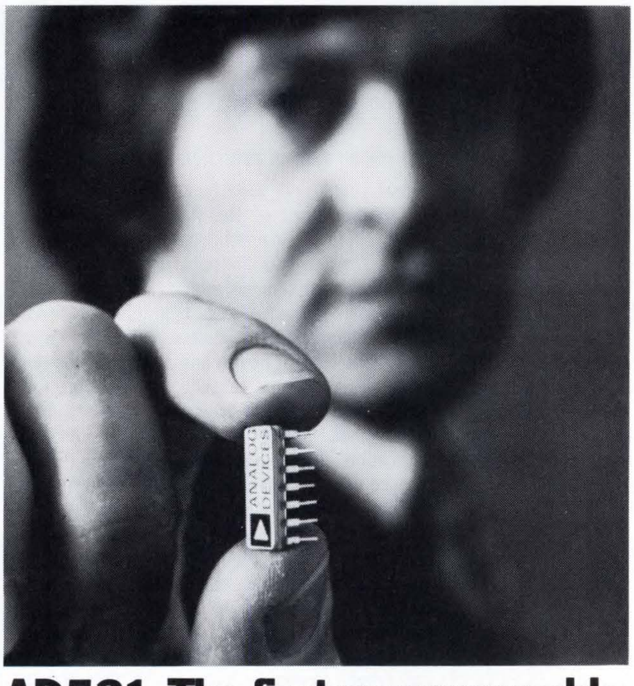

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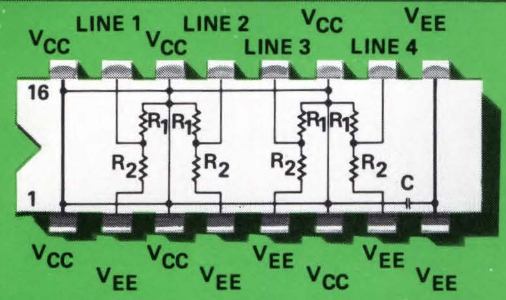

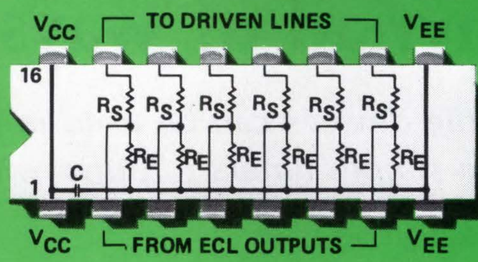

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Put the IC timer to work in a myriad of ways

These versatile devices can be used in numerous applications ranging from simple timers to pulse-width modulators.

Eugene R. Hnatek, Signetics Corp.

The introduction of the first integrated circuit timer last year added a new dimension to the field of linear integrated circuits. Since then these versatile timing circuits have replaced both thermal relays and electromechanical devices in a variety of timing functions. Their popularity is such that they are now made by at least three manufacturers: Signetics, National Semiconductor and Texas Instruments.

The salient features which make the IC timers useful in a wide variety of applications include:

- One-shot operation from microseconds through minutes
- Typical one-shot temperature stability of 40 ppm
- Oscillator operation up to 300 kHz
- Push-pull output capable of sinking or sourcing up to 200 mA of current.

This article will describe the various modes of operation of the new timers and the types of applications for which they are suited.

Monostable operation

Probably the most popular timer mode is monostable (one-shot) operation. **Fig. 1** shows a block diagram of the IC timer, in this case the Signetics NE/SE555, plus the external circuitry needed for monostable operation.

In operation, the external capacitor is initially held discharged by a transistor inside the timer. Upon application of a negative trigger pulse to pin 2, the flip-flop is set. This releases the short circuit across the external capacitor and drives the output HIGH. The voltage across the capacitor now increases exponentially with a time constant $\tau = R_AC$. When the voltage across the capacitor equals 2/3 V_{CC}, the comparator resets the flip-flop which, in turn, discharges the capacitor rapidly and drives the output to its LOW state.

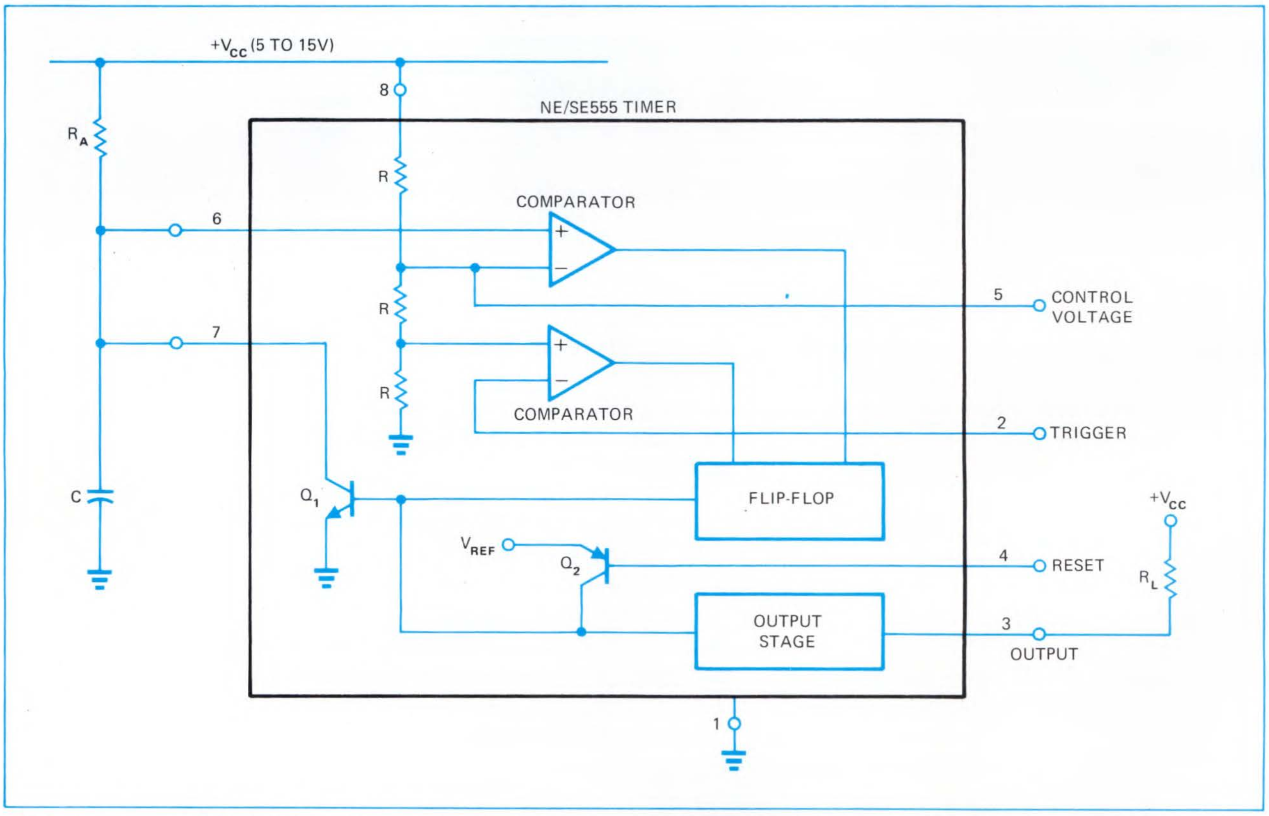

Fig. 1—For monostable operation, timing of the 555 timer is controlled by the time constant of external components R_A and C.

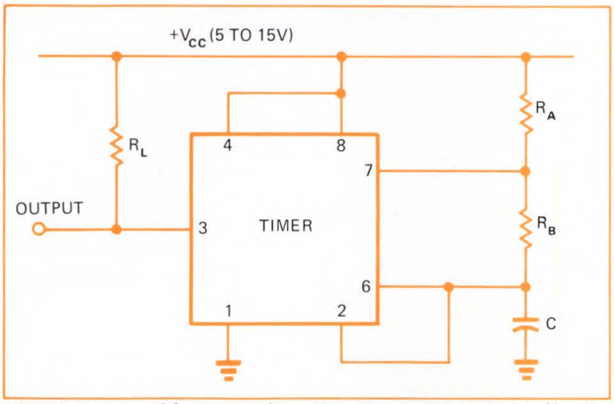

Fig. 2—In astable operation the timer triggers itself. The free-running duty cycle is controlled by the ratio of R_A to R_B.

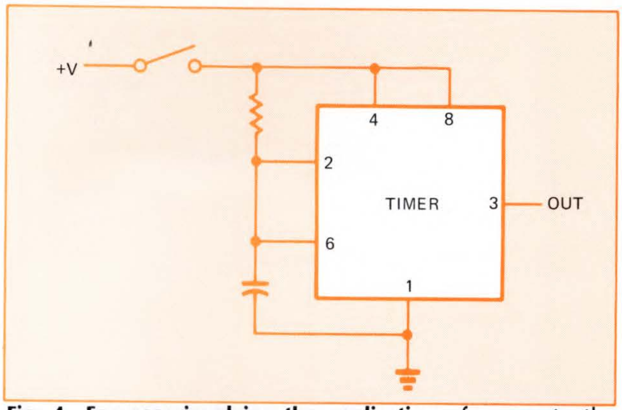

Fig. 4—For uses involving the application of power to the timer, the trigger input (pin 2) should be tied to pin 6. This holds the trigger LOW while input power is building up, thus insuring proper triggering.

Once triggered, the circuit remains that way until the set time is elapsed, even if it is triggered again during this interval. Since both the charge rate and the threshold level of the comparator are directly proportional to supply voltage, the timing interval is independent of supply voltage. Applying a negative pulse simultaneously to the reset terminal (pin 4) and the trigger terminal (pin 2) during the timing cycle discharges the external capacitor and causes the cycle to start over again. The timing cycle will now commence on the positive edge of the reset pulse. During the time the reset pulse is applied, the output is driven to its LOW state. When the reset function is not in use, it is recommended that it be connected to V_{CC} to avoid any possibility of false triggering.

Astable operation

If the timer is connected as shown in **Fig. 2** (pins 2 and 6 connected), it will trigger itself and operate as a free-running multivibrator. The external capacitor charges through R_A and R_B and discharges through R_B only. Thus, the duty cycle may be precisely set by the ratio of these two resistors.

In this mode of operation, the capacitor charges and discharges between 1/3 V_{CC} and 2/3 V_{CC}. As in the triggered mode, the charge and discharge times, and therefore the frequency, are independent of the supply voltage.

The charge time (output HIGH) is given by:

$$t_1 = 0.693\,(R_A + R_B)\,C$$

and the discharge time (output LOW) by:

$$t_2 = 0.693\,(R_B)\,C$$

Thus, the total period is given by:

$$T = t_1 + t_2 = 0.693\,(R_A + 2R_B)\,C$$

The frequency of oscillation is then:

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2R_B)\,C}$$

And the duty cycle is given by:

$$D = \frac{R_B}{R_A + 2R_B}$$

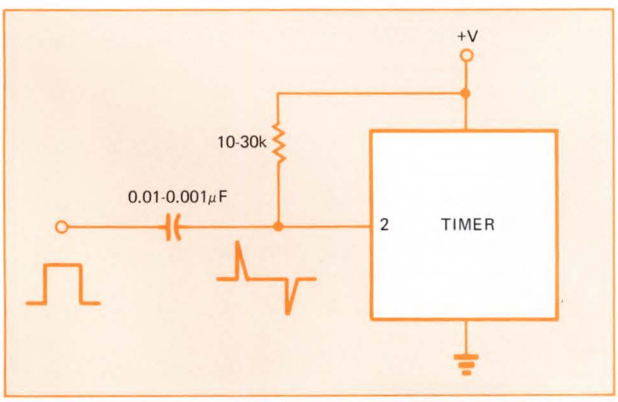

Fig. 3—To prevent triggering on the positive-going transition of a logic-type trigger signal, ac coupling should be used for the trigger input.

Application hints

As mentioned previously, triggering of the timer occurs on the negative-going edge of the trigger pulse. The threshold which must be attained for triggering is less than $V_{cc}/3$. A significant problem arises, though, when the trigger terminal is held at ground potential. Although the output will switch to a ONE state and will normally time out as expected, erratic time intervals will result if the trigger terminal is held at ground for long periods relative to the required timing cycle.

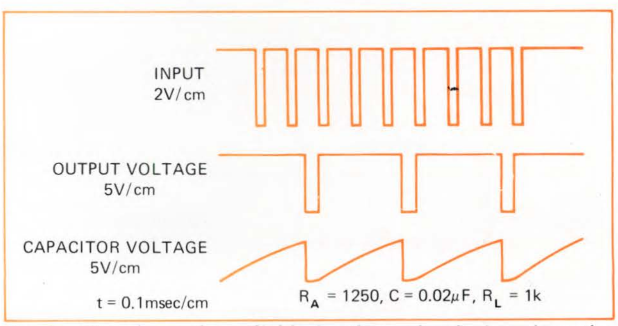

Fig. 5—Waveforms for a divide-by-three circuit show how the circuit of **Fig. 1** can be used for frequency division.

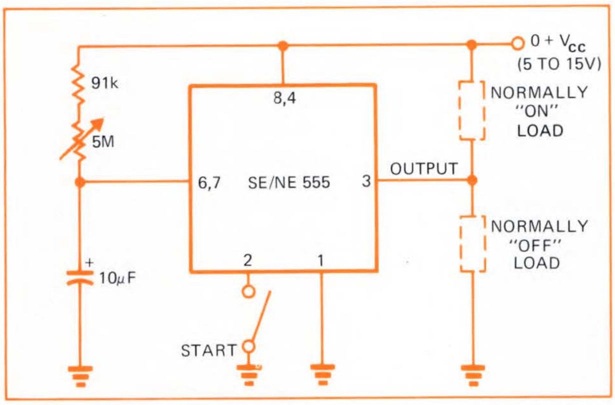

Fig. 6—When the 555 is used as a manually started timer, both a normally ON and normally OFF load can be controlled.

Another problem that can occur is that the trigger terminal may respond to positive-going transitions rather than negative ones when it is driven from a logic source. To avoid this, triggering should either be generated from the unit's own timing capacitor, as in the oscillator mode, or ac coupled through a 0.01- to 0.001-μF capacitor, as shown in **Fig. 3**. A pull-up resistor of 10-30 kΩ should also be included from pin 2 to V_{CC}.

Many uses of the timer involve the application of power to the device, i.e., a delay or a time-operating function is generated when V_{CC} is applied. The problem here is that reliable triggering must be guaranteed during the power application period. If, for instance, a slow-rising supply voltage is used, no trigger information may be produced. Also, application of power via a switch often produces spikes caused by contact bounce, and these will trigger the device most of the time. Therefore, the function desired may or may not take place.

The solution to these problems is shown in the circuit of **Fig. 4**. By tying the trigger to pin 6, the timing capacitance holds the trigger LOW while power is coming up. Triggering is then guaranteed, and timing occurs in the normal manner. However, V_{CC} must be removed from this circuit

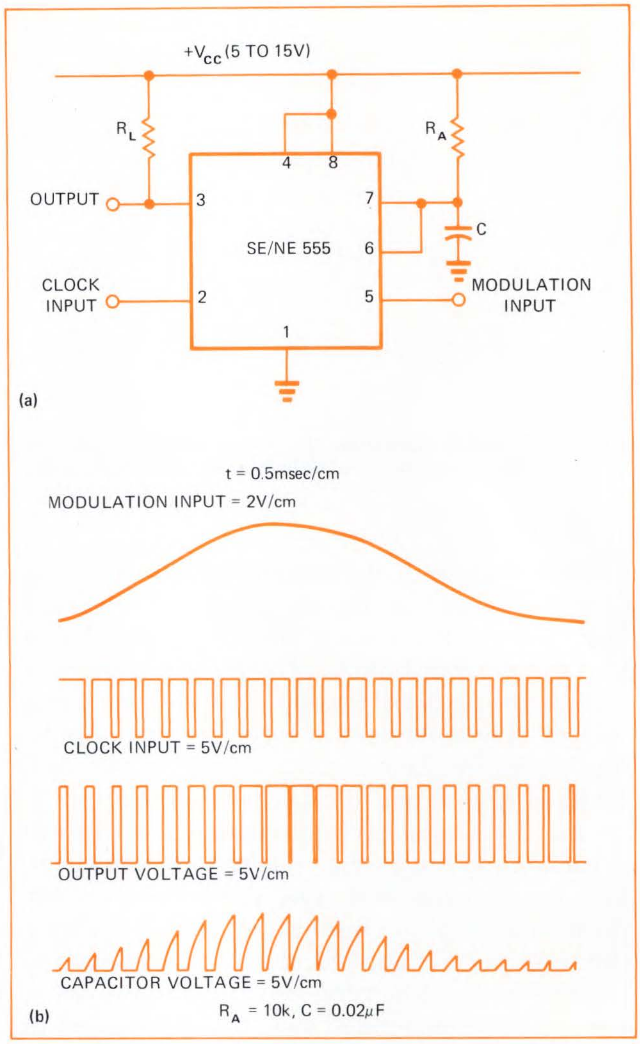

Fig. 8—For pulse width modulation the amplitude of a signal applied at pin 5 controls the pulse width of a pulse train applied to pin 2.

before retriggering can occur for the next cycle.

Frequency divider

If the input frequency is known, the timer can easily be used as a frequency divider by adjusting the length of the timing cycle. **Fig. 5** shows the waveforms of the timer of **Fig. 1** when used as a divide-by-three circuit. This application makes

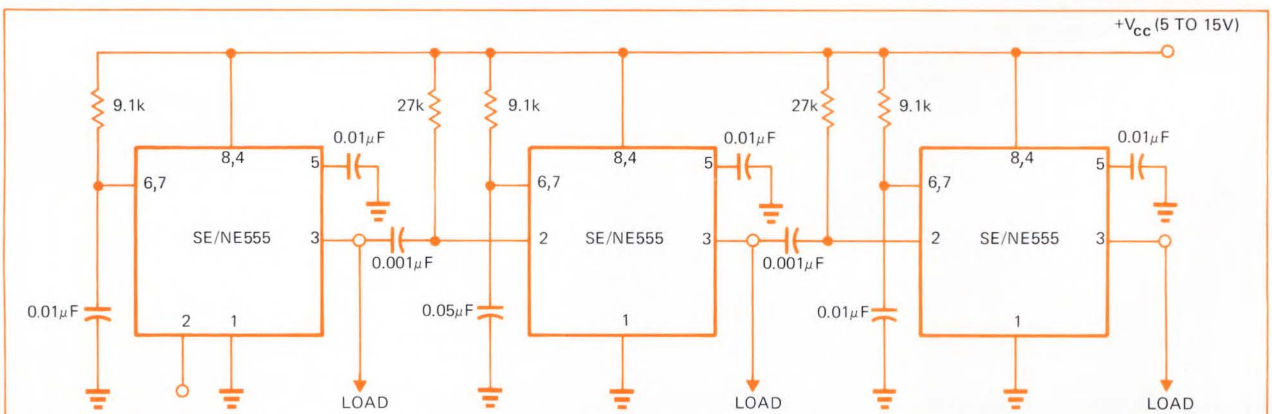

Fig. 7—Test sequencing is possible by connecting a number of timers in tandem.

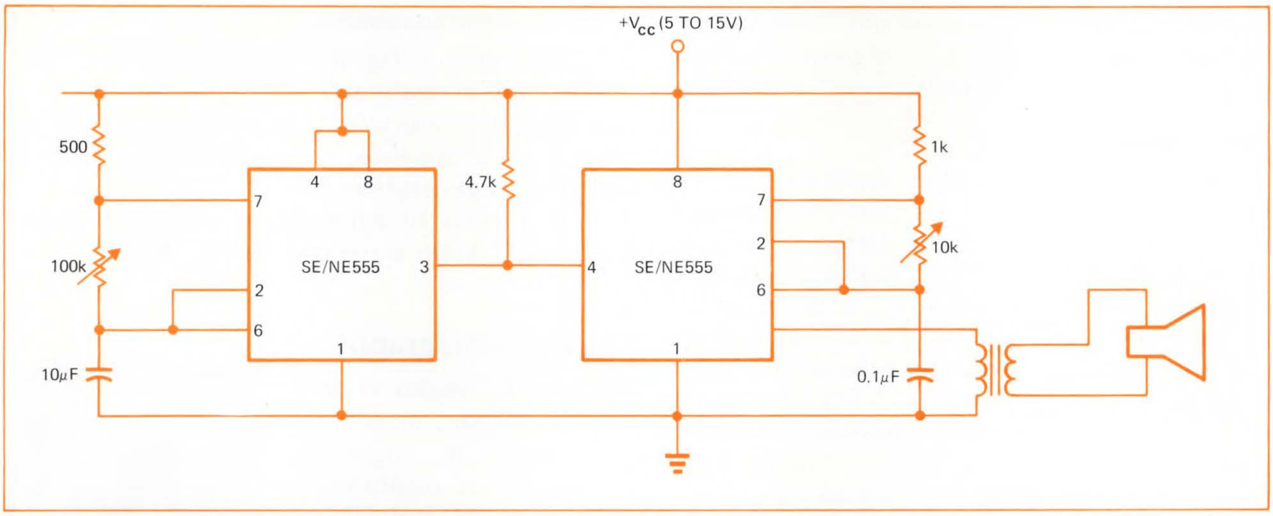

Fig. 9—In a tone-burst oscillator application, one timer is used as a slow astable multivibrator and a second as an audio-frequency oscillator.

use of the fact that the circuit cannot be retriggered during the timing cycle.

Manually started timer

Fig. 6 shows the NE555 connected as a manually started timer. The time can be set from 1 to 60 seconds either with a potentiometer or with a thumb-wheel switch and fixed resistors. Two loads, one normally ON, the other normally OFF,

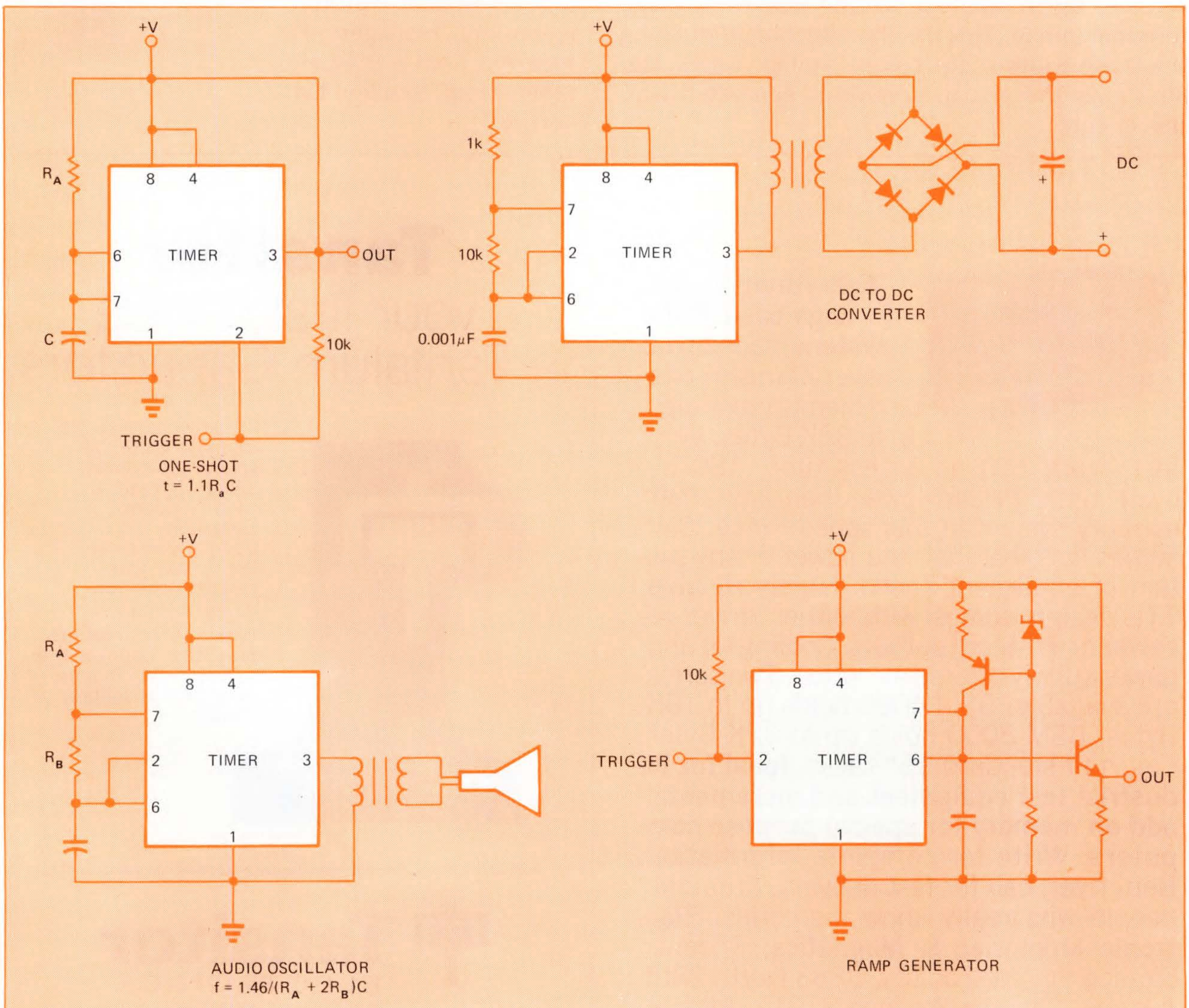

Fig. 10—A wide variety of additional applications are possible with IC timers.

can be connected to the circuit simultaneously. In this application, the circuit could power a relay, a lamp or a controlled rectifier.

Test sequencer

Test sequencing is another application for the IC timer. **Fig. 7** shows several timers connected sequentially. The first timer is started, either with a pulse or by momentarily connecting terminal 2 to ground, and runs for 10 msec. At the end of its timing cycle, it triggers the second circuit, which runs for 50 msec; after this time the third circuit is triggered. It should be noted that the timing resistors could be digitally programmed in this application. Also each circuit could easily trigger several other timers to start similar concurrent sequences.

Pulse-width modulator

In this application, the timer is connected in the monostable mode as shown in **Fig. 8a**. The circuit is triggered with a continuous pulse train (clock input) while the threshold voltage is modulated by the signal applied to the control voltage terminal (pin 5). This has the effect of modulating the pulse width as the control voltage varies. **Fig. 8b** shows the actual waveforms generated with this circuit.

Tone-burst oscillator

In this circuit (**Fig. 9**), the first timer is a slow astable multivibrator whose output is used to gate an audio-frequency oscillator on and off through the reset terminal (pin 4) to provide repeatable tone-burst generation.

Other types of applications that are possible with an IC timer are shown in **Fig. 10**. □

Author's biography

Eugene R. Hnatek is presently linear marketing manager at Signetics Corp. He is responsible for new product development, advertising and management of the entire linear product line. Gene was previously with National Semiconductor Corp., where he was military/aerospace product marketing manager. He received both a BSEE and MSEE from Bradley University.

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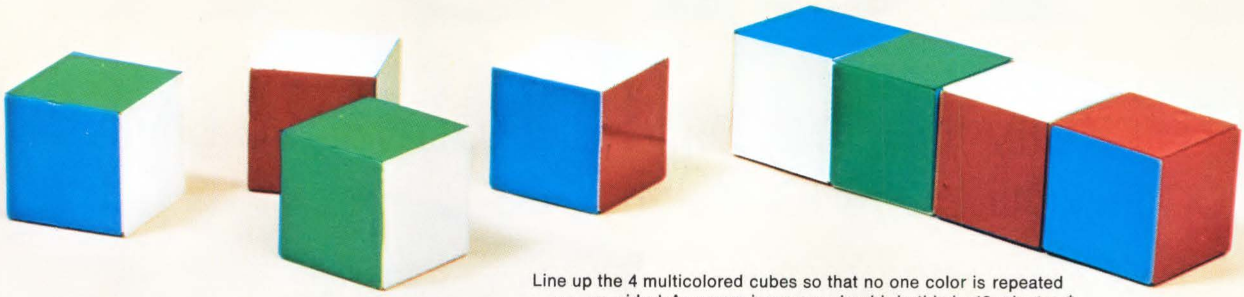

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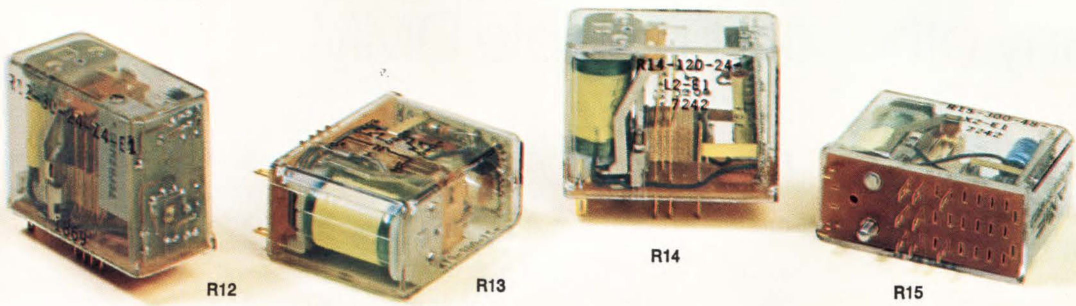

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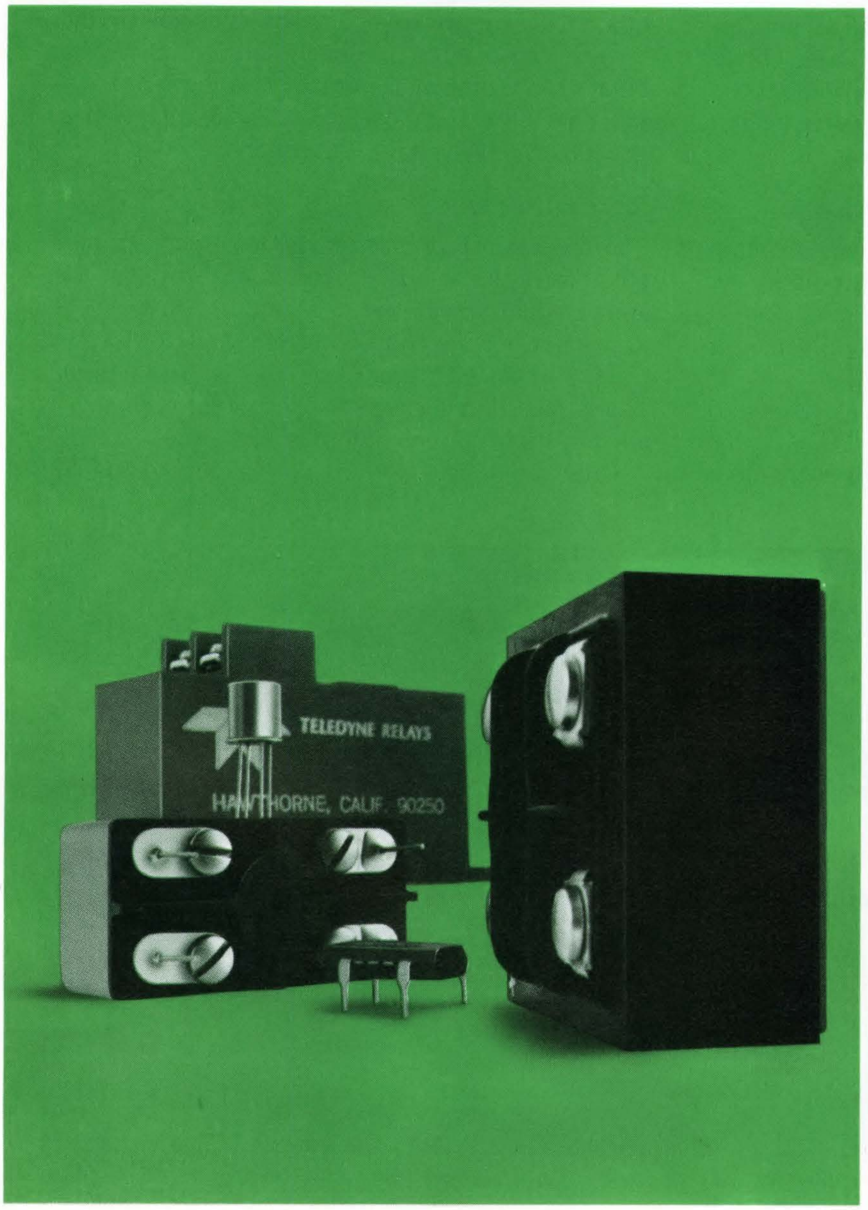

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CHECK NO. 39

Simplified methods characterize optical couplers

Either an oscilloscope or a transistor curve tracer can be used to display the current transfer characteristic of an optical coupler.

Robert H. Dotson, Motorola, Inc., Semiconductor Products Div.

Optical couplers have found a wide variety of applications in both pulse and linear circuits. But their usefulness in linear circuits is somewhat limited by the nonlinearities of their current transfer curve (input current versus output current at constant collector voltage). This curve varies from device to device, and at times it is necessary to know the current transfer curve for a given coupler. These curves can be generated with usable accuracy either on a standard oscilloscope or on a transistor curve tracer.

On an oscilloscope

The isolated nature of an optical coupler makes it very simple to display input current versus output current on an oscilloscope without polarity or grounding problems. A circuit for doing this is shown in **Fig. 1a**, and a typical display obtained is shown in **Fig. 1b**.

Pulsating full-wave rectified 60-cycle voltage is applied to the light-emitting diode (LED) of the optical coupler. The LED input current is proportional to the voltage across the 100Ω resistor, and that voltage is connected to the oscilloscope horizontal circuit. Similarly, the output current of the coupler is proportional to the voltage across the 10Ω resistor, and that voltage is connected to the oscilloscope vertical circuit. V_{CE} is approximately constant and equal to the supply voltage to the collector circuit. This is because at the maximum collector current of about 40 mA, the voltage drop across the 10Ω resistor is only 0.4V. Therefore, V_{CE} will vary by less than 10% if the supply voltage is 5V or above.

On a curve tracer

To use a transistor curve tracer to display the current transfer characteristic of an optical coupler, the arrangement shown in **Fig. 2** is used. For all practical purposes, when the coupler is connected in this way, it acts like an NPN transistor (**Fig. 3**). The transfer ratio is just the effective "Beta" (output current divided by input current) multiplied by 100%.

A test jig using a 14- or 16-pin dual-in-line IC

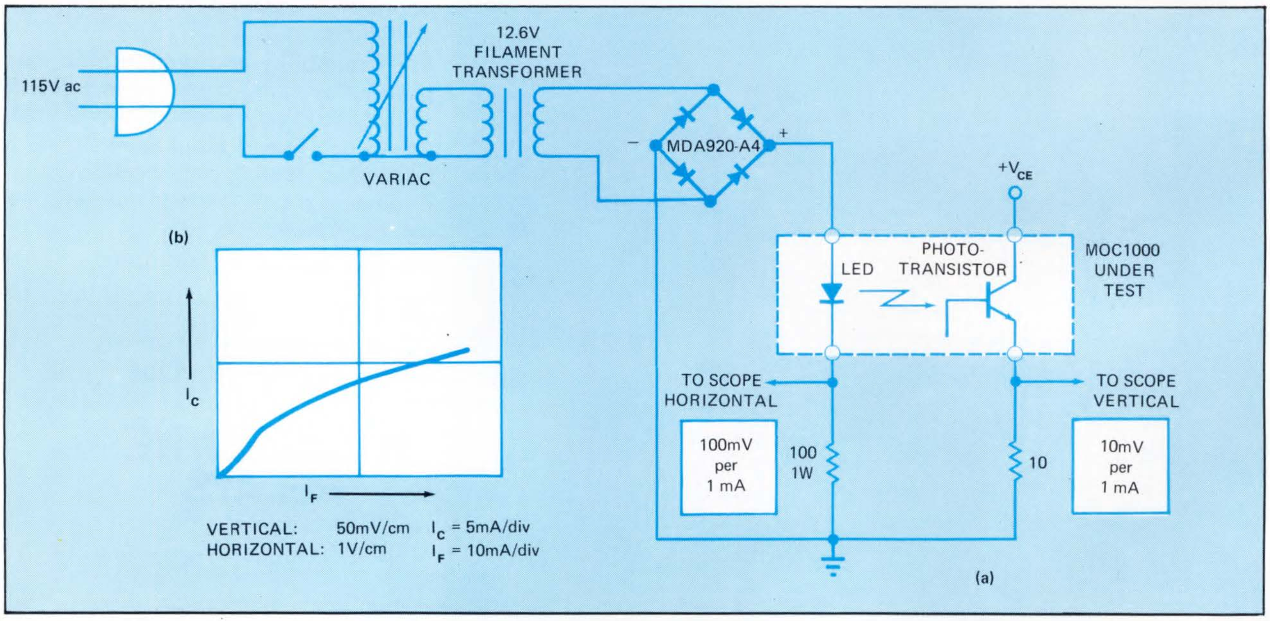

Fig. 1 – Oscilloscope display of optical coupler current transfer characteristic is generated with voltages developed by the coupler input and output currents (**a**). Typical display waveform is shown in (**b**).

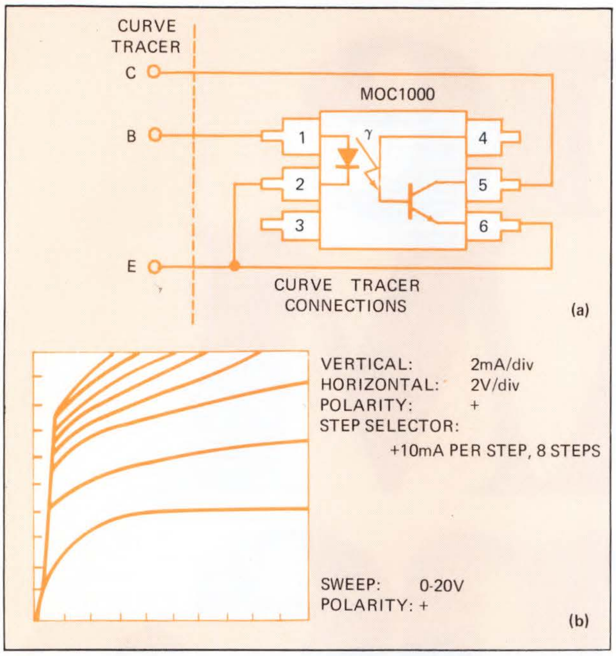

Fig. 2—Curve tracer display of current transfer characteristic is accomplished as in (**a**) and produces families of curves as in (**b**).

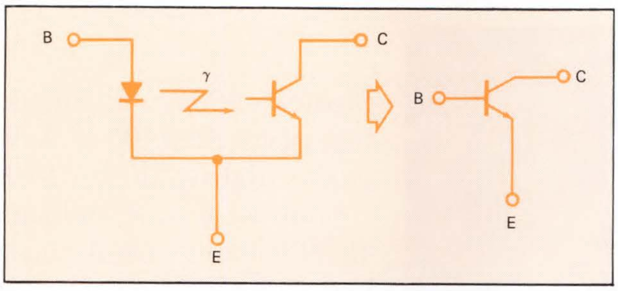

Fig. 3—The optical coupler is equivalent to an NPN transistor when it is connected to the curve tracer for transfer characteristic measurements.

socket can be readily made which will plug directly into the curve tracer and implement the testing of a large number of couplers. Note also that this same technique can be used to test other types of optical couplers, such as LED-photodiode and LED-photoDarlington pairs, by adjusting the input and output requirements to suit the device. □

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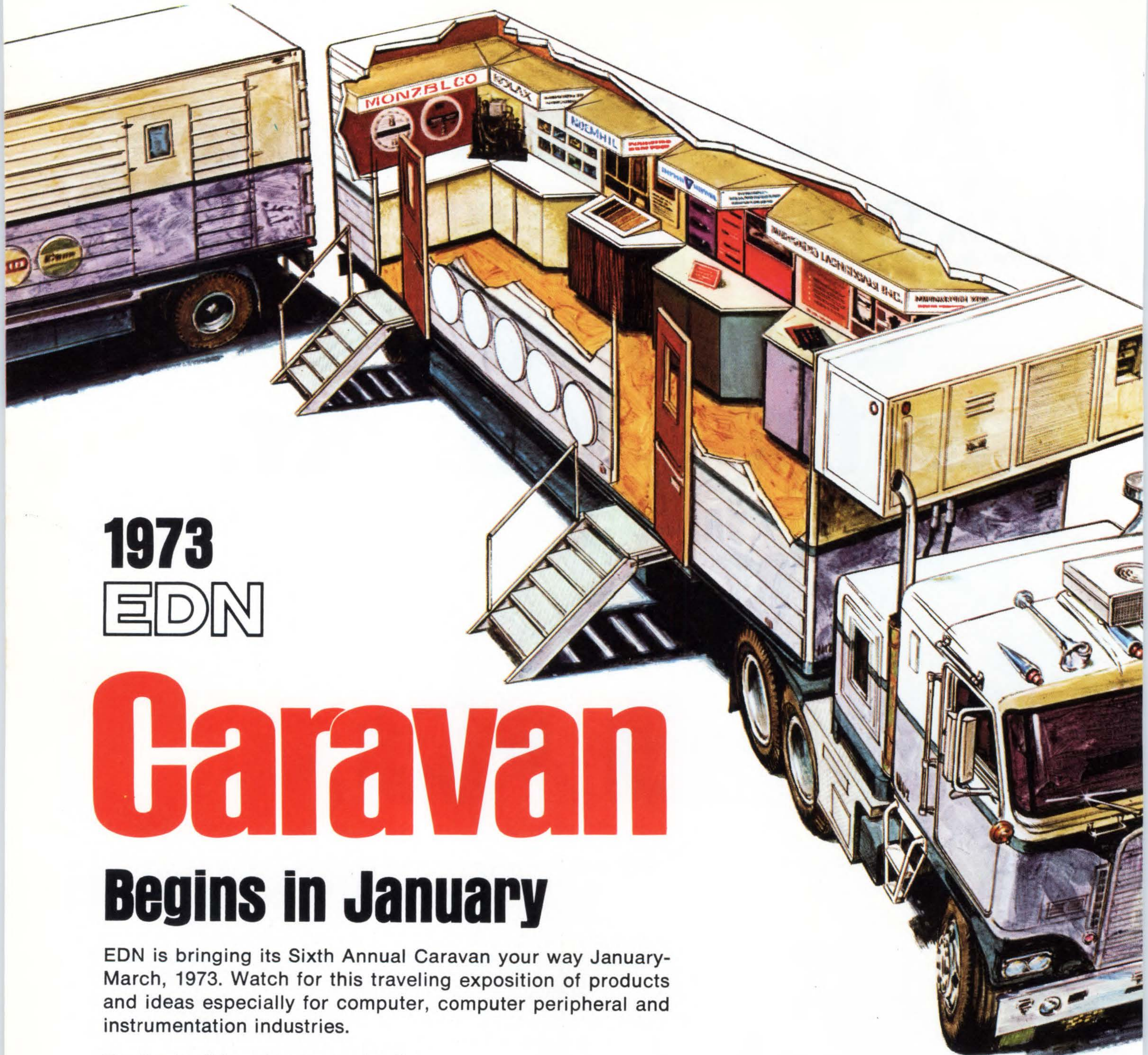

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March 1 A.M.	Thursday 9:00-11:30	*	Telex Computer Products, 6422 East 41st Street, Tulsa, (Parking: Sheridan Entrance - Rear of Building)
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March 8 A.M.	Thursday 9:00-11:30	#	Control Data Corporation, 4625 West 77th Street, Minneapolis, Minnesota
March 8 P.M.	Thursday 2:00-4:30	#	Sperry Rand/UNIVAC, 2276 Highcrest Drive, Roseville, Minnesota
	INVITEE		Sperry/UNIVAC/EMR Products
March 9 A.M.	Friday 9:00-11:30		Sperry Rand, Federal Systems Division, 2750 West 7th Boulevard, St. Paul, Minnesota
March 9 P.M.	Friday 2:00-4:30	#	Control Data, 4201 Lexington Avenue, St. Paul (Arden Hills), Minnesota
March 12 Day (AM-PM)	Monday 10:00-1:30	#	Bell Telephone Labs, Naperville, Illinois
March 12 P.M.	Monday 2:00-4:30	#	Western Electric, 4513 Western Avenue, Lisle, Illinois
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Tailor the response of your active filters

Here's a technique for emphasizing or de-emphasizing the response curve at specific frequencies and at specific gain or attenuation rates.

Bjorn Brandstedt, McDonnell-Douglas Corp.

The design of "standard" active filter types such as Tchebyscheff, Butterworth, etc., is fairly well established in terms of the integrated circuit operational amplifier. Often, though, engineers are called on to design band-pass filters where the response curve must be emphasized or de-emphasized at specific frequencies and at specific gain or attenuation rates. The standard design procedures must then be modified. One way of doing it is described in this article. This technique has successfully been employed to realize weighting and equalizing networks for audio applications.

The transfer function

The transfer function on which this technique is based contains real and complex zeros which are most useful, if not necessary, in weighting and emphasis network design. The general form of the transfer function is

$$T(s) = -K\frac{(s+\omega_1)(s^2+2\omega_3 z_1 s+\omega_3^2)(s+\omega_5)}{(s+\omega_2)(s^2+2\omega_4 z_2 s+\omega_4^2)(s+\omega_6)} \quad \textbf{(1)}$$

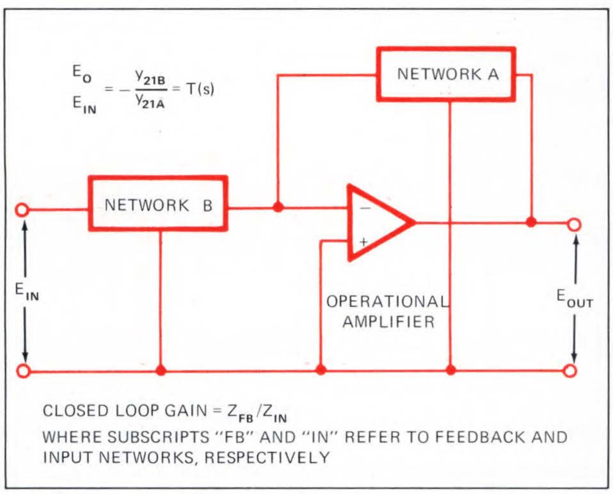


Fig. 1—An input network (B) and a feedback network (A) are used with the op amp to implement the transfer function of **Eq. 1**.

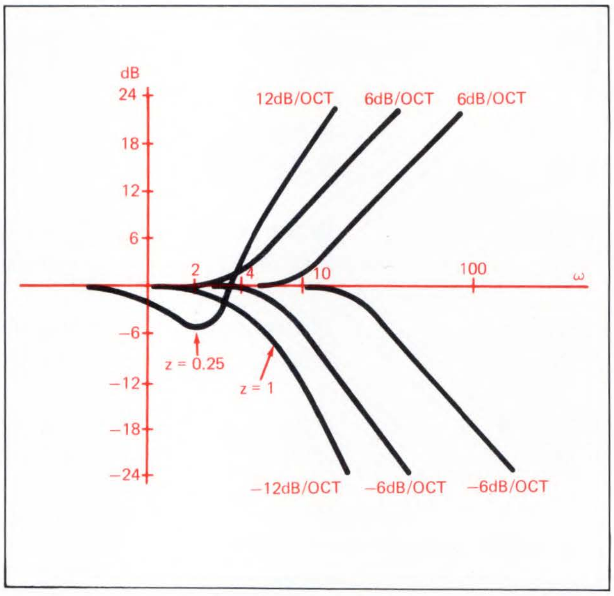


Fig. 2—Log-dB Bode plot of T(s) consists of six individually variable components.

Using the procedure that follows it is possible to realize **Eq. 1** with only one operational amplifier. Any pair of zeros and/or poles, complex or real, may easily be made to cancel if they are not required. Furthermore, all poles or zeros are taken care of at one time, thus minimizing design calculations. That is, once the function has been determined, all zeros are designed into one network and all poles into a second. The operational amplifier configuration used to realize the desirable relationship between the two networks is shown in **Fig. 1**. This configuration allows us to readily invert T(s) for de-emphasis should that be called for in a particular signal processing system.

The gain of T(s) namely K, is the familiar closed-loop dc-gain, Z_{FB}/Z_{IN}, of **Fig. 1**. Using only a single operational amplifier and networks having a potential of four poles and four zeros, provides the inherent advantages of lower component count, power drain and cost.

The design procedure

It has been found that the simplest approach to emphasis network design is to determine the desired T(s) from approximations on a log-dB Bode plot, and then synthesize the so derived T(s). The gain function of T(s) is

$$G = 20\log_{10}\frac{1}{k} + 20\log_{10}|j\omega + \omega_1| + 20\log_{10}|2\,\omega_3 z_1\, j\omega + \omega_3^2 - \omega^2| + 20\log_{10}|2\,\omega_4 z_2\, j\omega + \omega_4^2 - \omega^2| - 20\log_{10}|j\omega + \omega_6| \quad (2)$$

Graphically, the function consists of six individually variable components plus the gain constant (**Fig. 2**). The gain constant, of course, does not affect the relative response. The response curve of T(s) is the sum of these components, as indicated in (**Eq. 2**). The idea in this particular approach to the derivation of T(s) is to manipulate the terms of **Eq. 2** in a manner that will cause them, when added, to exhibit the desired frequency response.

The designer must keep in mind that undesired terms will cancel in pairs only. So if only complex conjugate poles are desired, the complex conjugate zeros must be located outside the region of interest.

When, in terms of **Fig. 1**, all break frequencies and damping constants have been selected, they are inserted into the general form of T(s) to produce the particular transfer function that is to be realized.

Design example shows how

The following example shows how the design procedure is carried out. In the example, frequency emphasis at a rate of 18 dB/octave is desired between 5 kHz and 15 kHz. At the break points, ±1 dB is tolerated. Behavior beyond 15 kHz is not critical but emphasis shall not exceed 40 dB at 20 kHz. **Fig. 3** shows the desired response curve with the terms of **Eq. 2** superimposed in a fashion that is likely to produce the desired response.

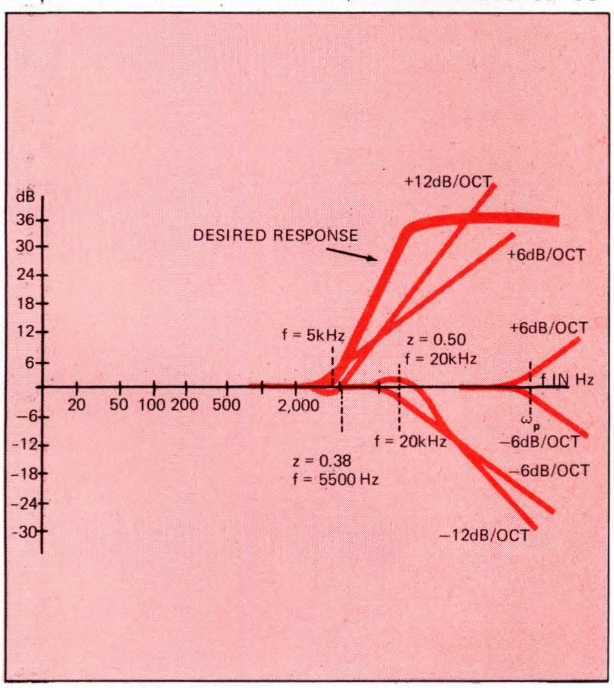


Fig. 3 – Desired response of 18 dB/octave emphasis network is produced by graphically manipulating the terms of **Eq. 2**.

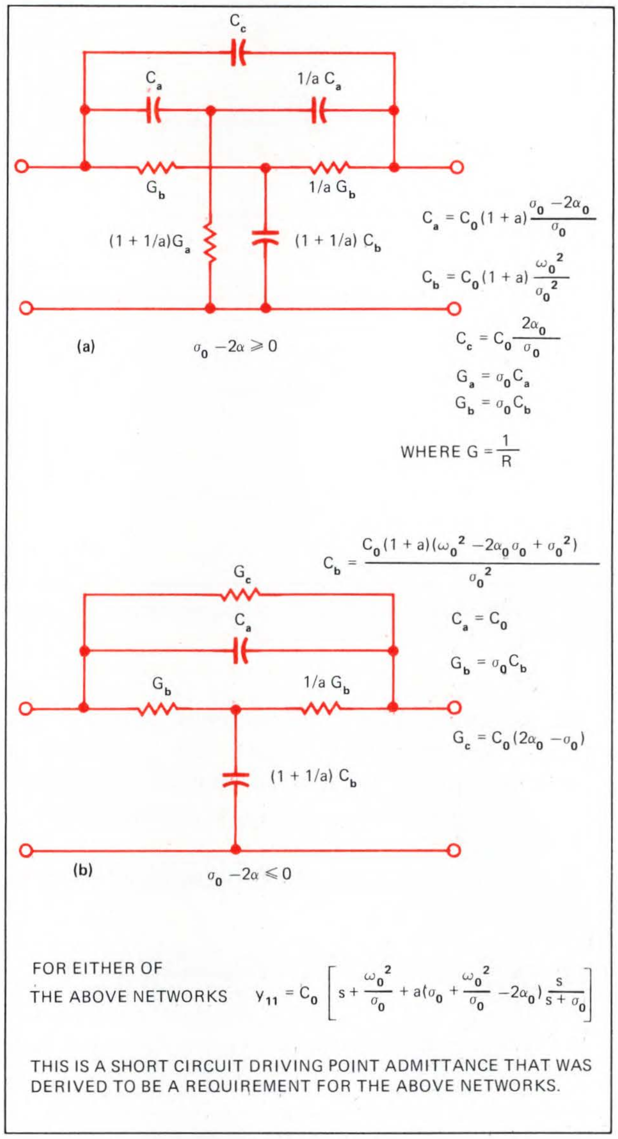


Fig. 4 – These are the networks used to implement **Eq. 5** and **6**. If $\sigma_o - 2\alpha > 0$, network **a** is used, and if $\sigma_o - 2\alpha \leq 0$, network **b** is used.

The asymptotes of the function are graphically added, subtracted and adjusted until the designer is satisfied enough to continue the procedure and to analyze the response of a breadboarded version of his function. This is a trial and error process. The slope, for example, is dependent on the damping constants of the quadratics and/or the relative location of their break frequencies.

The thing that makes it difficult to use the asymptote method with the quadratics is the damping constant which, for small values, causes the true curve to deviate a great deal from the asymptotes, and as a result, the log-dB method loses some simplicity.

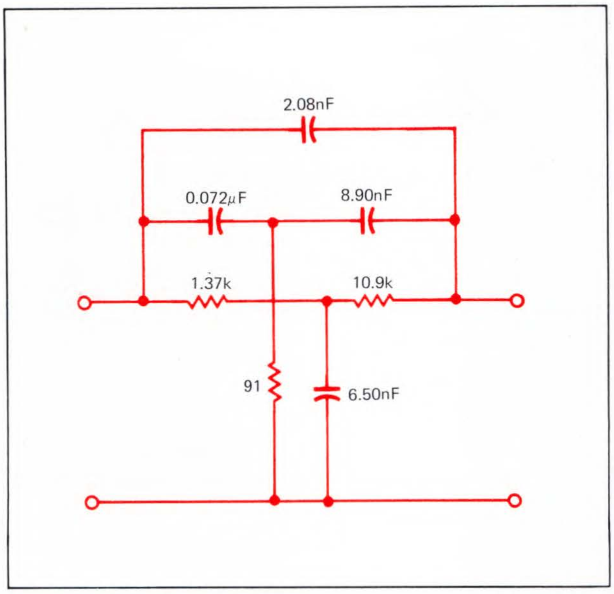


Fig. 5—The input network of the design example has these calculated component values prior to scaling.

The minimum value of the damping constant (z) is zero and the maximum value is unity, since for z greater than unity the roots are real and two linear terms may be used. This synthesis method thus requires $0 < z \leq 1$.

To continue the example the following is obtained from **Fig. 3**:

$$T(s) = \frac{(s + 2\pi 5000)[s^2 + 4\pi 5500(0.38)s \ldots}{(s + 2\pi 2 \times 10^4)[s^2 + 4\pi 2 \times 10^4(0.50)s \ldots} \qquad \frac{+ (2\pi 5500)^2]}{+ (2\pi 2 \times 10^4)^2]} \tag{3}$$

For the circuit configuration of **Fig. 1**,

$$T(s) = -\frac{y_{21B}}{y_{21A}} \tag{4}$$

where

$$y_{21B} = \frac{[s^2 + 4\pi\ 5500(0.38)s + (2\pi\ 5500)^2]}{(s + 2\pi\ 2 \times 10^4)(s + \omega_p)} \tag{5}$$

$$y_{21A} = \frac{[s^2 + 4\pi\ 2 \times 10^4(0.50)s + (2\pi\ 2 \times 10^4)^2]}{(s + 2\pi 5000)\ (s + \omega_p)} \tag{6}$$

The terms that are left as unknowns in **Eq. 5** and **6** are selected to cancel in this application because they are not required.

Now begins the actual synthesis procedure, which is based on Dasher's synthesis procedure[1], and in this simplified case boils down to the determination of element values for either of the networks shown in **Fig. 4**.

The steps can be traced from the formal procedure, but need not be general here and have thus been simplified considerably.

1. We begin by realizing y_{21B}.

The parameters α_o and ω_o are determined from the location of the zero in the upper left-half plane. The pertinent root of the quadratic term of y_{21B} is

$$S_o = -\frac{2.64 \times 10^4}{2} + \sqrt{\frac{6.91 \times 10^8 - 4 \times 11.9 \times 10^8}{4}}$$

$$= -1.32 \times 10^4 + j\,3.14 \times 10^4 \tag{7}$$

(location of zero in upper half plane)

NOW, $S_o = -\alpha_o + j\beta_o = \omega_o < \theta°$

SO, $\alpha_o = 1.32 \times 10^4$

$\omega_o^2 = 1.012 \times 10^9$

2. Normally the starting point is a specified y_{11} and y_{12} ($y_{12} = y_{21}$ for passive networks). In this modified procedure we "assemble" the y_{11} as we go along in order to simplify the process by selecting the most convenient poles and zeroes.

Consequently, the poles of y_{11} and y_{21} will be the same. There are no real zeros in y_{21}.

y_{11} shall be in the form of a ratio of a quadratic to a linear function. This is normally accomplished by producing an admittance pole at infinity. It is realized as a series resistor which is omitted here because of its negligible effect. The remainder when the admittance pole has been produced is y_R which, without a previously specified y_{11} is directly approximated as

$$y_R = \frac{(s + \omega_o^2/\omega_z)(s + \omega_z)}{\omega_p(s + \sigma_o)} \tag{8}$$

which has the desired form of a ratio of a quadratic to a linear function. This is a very close approximation, where the requirement for ω_z is

$$\sigma_o < \omega_z < \omega_p \tag{9}$$

In our example, then

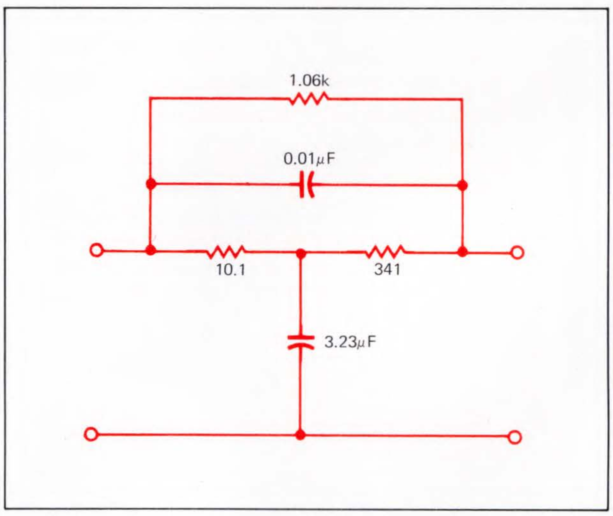


Fig. 6—The feedback network of the design example has these calculated component values prior to scaling.

$$y_R = \frac{(s + 1012)(s + 10^6)}{10^8(s + 1.26 \times 10^5)}$$

$$= \frac{s^2 + 1.001 \times 10^6 s + 1.012 \times 10^9}{10^8(s + 1.26 \times 10^5)}$$

$$y_R \cong \frac{s^2 + 10^6 s + 10^9}{10^8(s + 1.26 \times 10^5)} \tag{10}$$

3. In order to compare the above admittance (**Eq. 10**) to the driving point admittance that was derived to be a requirement for the networks of **Fig. 4**, we now obtain a partial fraction expansion of y_R/s. It is of the form

$$b_\infty + \frac{b_o}{s} + \frac{b_1}{s + \sigma_o} \tag{11}$$

$$\frac{y_R}{s} = \frac{s^2 + 10^6 s + 10^9}{10^8(s + 1.26 \times 10^5)s}$$

$$= b_\infty + \frac{b_o}{s} + \frac{b_1}{s + 1.26 \times 10^5}$$

$$s^2 \times 10^{-8} + 10^6 \times 10^{-8} s + 10^9 \times 10^{-8}$$
$$= (s + 1.26 \times 10^5) s\, b_\infty + (s + 1.26 \times 10^5)$$
$$b_o + b_{1\,s} = s^2 b_\infty + 1.26 \times 10^5 b_\infty s + b_o s$$
$$+ 1.26 \times 10^5 b_o + b_1 s$$

The equating coefficients:

$$10^{-8} = b_\infty$$
$$10^{-2} = 1.26 \times 10^5 b_\infty + b_o + b_1$$
$$10 \quad = 1.26 \times 10^5 b_o$$

$$b_o = \frac{10}{1.26 \times 10^5} = 8.04 \times 10^{-5}$$

$$10^{-2} = 1.26 \times 10^5 \times 10^{-8} + \frac{10}{1.26 \times 10^5} + b_1$$

$$b_1 = 10^{-2} - 1.26 \times 10^{-3} - 8.04 \times 10^{-5}$$
$$= 8.66 \times 10^{-3}$$

So, $b_\infty = 10^{-8}$
$b_o = 8.04 \times 10^{-5}$
$b_1 = 8.66 \times 10^{-3}$

4. By comparing the derived y_{11} with the above expansion, we now obtain the remaining unknowns. Multiplying **Eq. 11** by s;

$$s\, b_\infty + b_o + \frac{b_1 s}{s + \sigma_o} \tag{12}$$

Factoring out b_∞,

$$b_\infty\left[s + \frac{b_o}{b_\infty} + \frac{b_1}{b_\infty}\left(\frac{s}{s + \sigma_o}\right)\right] \tag{13}$$

From **Fig. 4**,

$$y_{11} = c_o\left[s + \frac{\omega_o^2}{\sigma_o} + a\left(\sigma_o + \frac{\omega_o^2}{\sigma_o} - 2\alpha_o\right)\frac{s}{s + \sigma_o}\right]$$

So, $c_o = b_\infty$ **(14)**

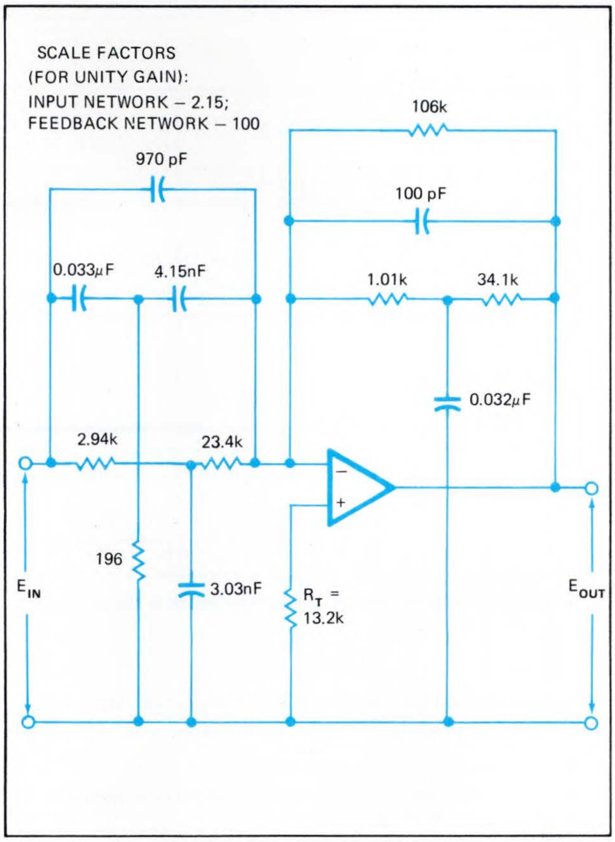


Fig. 7—The completed filter network has the indicated component values after scaling.

$$a\left(\sigma_o + \frac{\omega_o^2}{\sigma_o} - 2\alpha_o\right) = \frac{b_1}{b_\infty}$$

$$a\left(1.26 \times 10^5 + \frac{10}{1.26 \times 10^5} - 2.64 \times 10^4\right)$$

$$= \frac{8.66 \times 10^{-3}}{10^{-8}}$$

$$\therefore a = 8.05 \tag{15}$$

5. Determine which network in **Fig. 4** to use by evaluating $\sigma_o - 2\alpha$.

$$\sigma_o - 2\alpha = 1.26 \times 10^5 - 2.64 \times 10^4$$
$$= 1.0 \times 10^5 > 0$$

Therefore, use the TEE-network of **Fig. 5** for the input network. This is network "B" in **Fig. 1**.

6. Calculate network component values according to the formulas given on **Fig. 4**.

$$C_a = 10^{-8}(9.05)\frac{(12.60 - 2.64) \times 10^4}{1.26 \times 10^5}$$

$$= 7.16 \times 10^{-8} \text{ farads}$$

$G_a = (1.26)(7.16) \times 10^{-3} = 9.00 \times 10^{-3}$ mhos $(= 111\ \Omega)$

$$C_b = 10^{-8}\frac{9.05 \times 10^9}{1.59 \times 10^{10}} = 5.78 \times 10^{-9} \text{ farads}$$

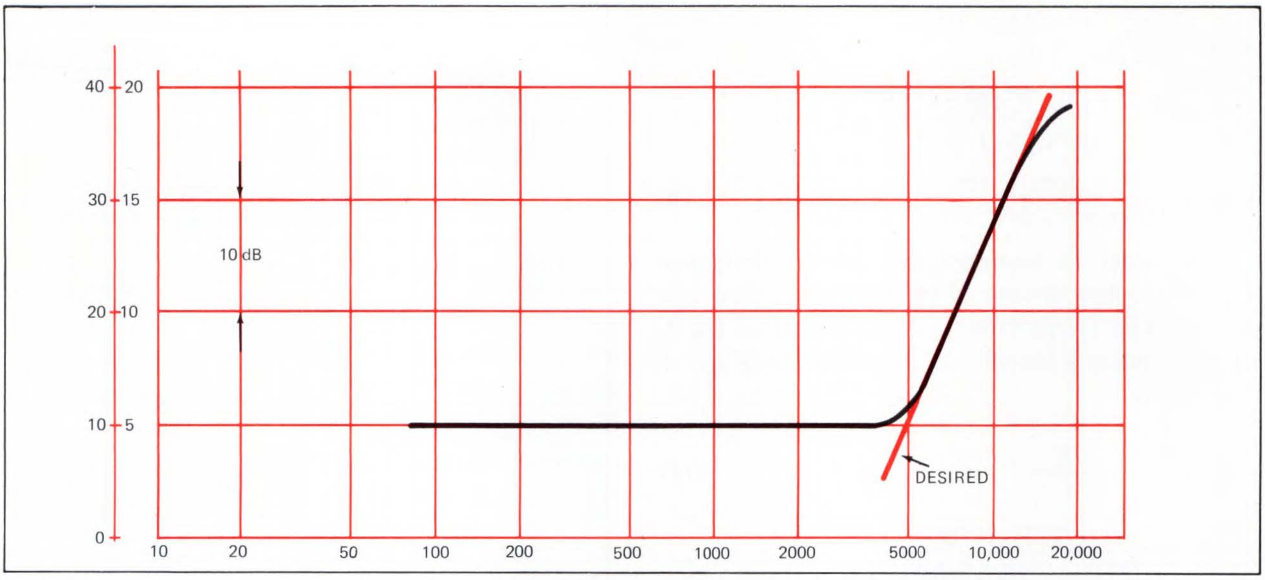


Fig. 8—The actual response of the final network is shown to be in close agreement with desired response.

$$G_b = (1.26)(5.78) \times 10^{-4} = 7.27 \times 10^{-4} \text{ mhos} \quad (= 1.37 \text{ k}\Omega)$$

$$C_c = \frac{10^{-8}\, 2.64 \times 10^4}{1.26 \times 10^5} = 2.08 \times 10^{-9} \text{ farads}$$

$$\frac{1}{a} C_a = (0.124) 7.16 \times 10^{-8} = 8.90 \times 10^{-9} \text{ farads}$$

$$\frac{1}{a} G_b = (0.124) 7.27 \times 10^{-4} = 9.16 \times 10^{-5} \text{ mhos}$$

$$(= 10.9 \text{ k}\Omega)$$

$$\left(1 + \frac{1}{a}\right) C_b = (1.124)(5.78) \times 10^{-9}$$

$$= 6.50 \times 10^{-9} \text{ farads}$$

$$\left(1 + \frac{1}{a}\right) G_a = (1.124)(9.00) \times 10^{-3}$$

$$= 1.10 \times 10^{-2} \text{ mhos } (= 91\ \Omega)$$

The result is shown on **Fig. 5**.

7. Repeat the procedure for the feedback network. The result is shown in **Fig. 6**.

8. Select a scale factor for the input network that yields reasonable component values. This is done simply by multiplying all resistors and dividing all capacitors by the same constant. The scale factor of the feedback network now depends on the desired closed-loop gain; so,

$$\text{scale factor}_{FB} = \frac{(\text{desired closed-loop gain})\ Z_{IN_{dc}}}{Z_{FB_{dc}}} \qquad \textbf{(16)}$$

The complete network is shown in **Fig. 7**.

9. The circuit of **Fig. 7** is bread boarded and the response evaluated. Usually, several adjustments must be made, with subsequent recalculation of component values, before a satisfactory result is achieved.

Once a design is acceptable, the dc drift is taken care of according to:

$$R_T = Z_{IN_{dc}} // Z_{FB_{dc}} \qquad \textbf{(17)}$$
$$= 26.3 \text{ k}\Omega // 26.4 \text{ k}\Omega$$
$$= 13.2 \text{ k}\Omega$$

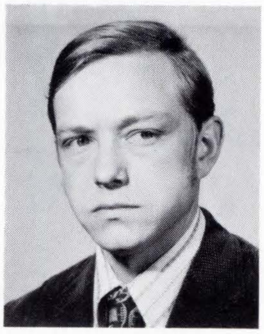
The operational amplifier is finally compensated for the chosen closed-loop gain, as per the manufacturer's specifications.

The final emphasis network response is shown in **Fig. 8**. ☐

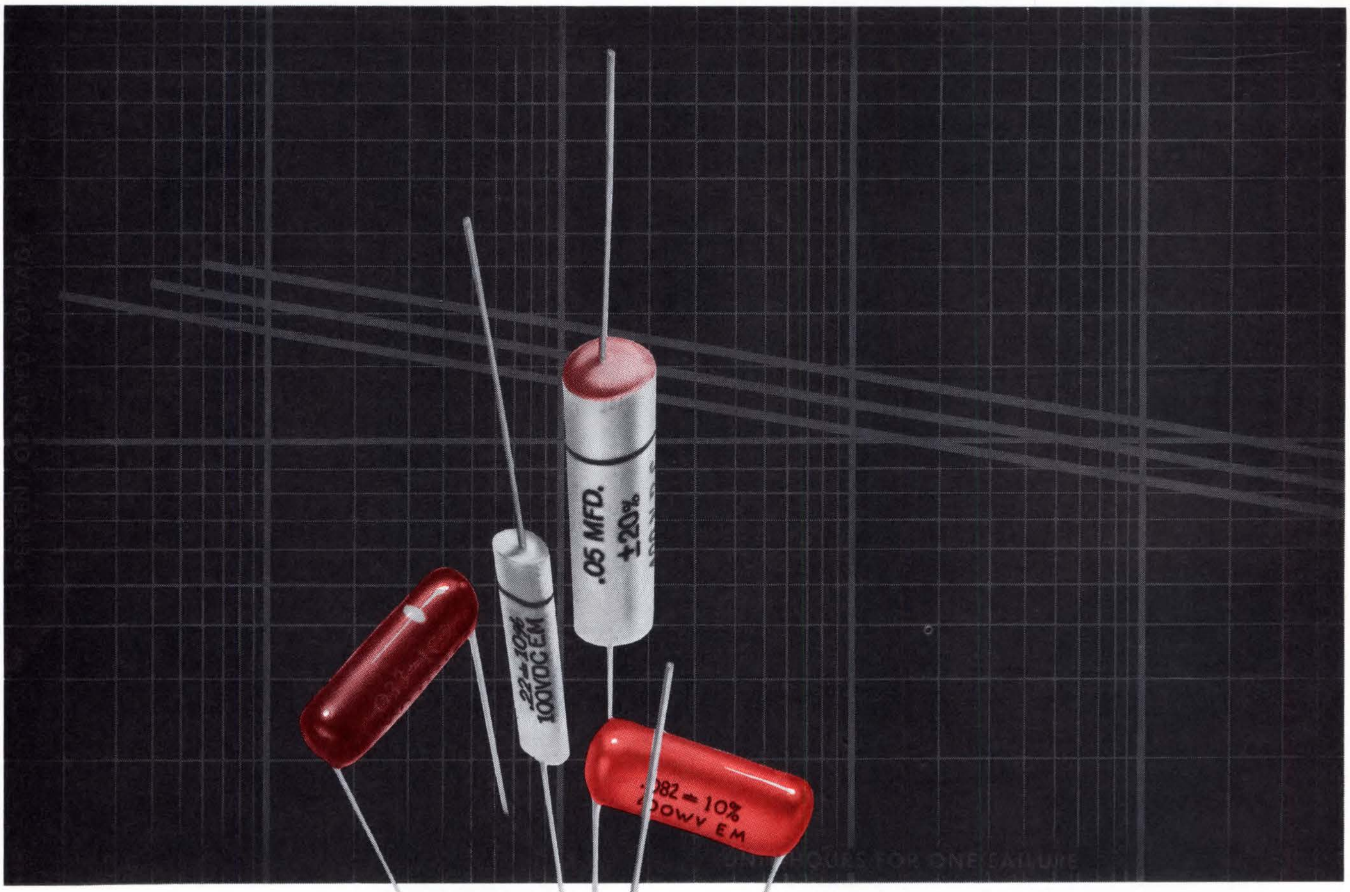
References

1. John G. Truxal, *Automatic Feedback Control System Synthesis*, McGraw-Hill Book Company, NY, 1955, p 206.
2. Op. Cit. p 211.
3. Ronald E. Scott, *Linear Circuits*, Addison-Wesley Publishing Co., Inc., MA, 1960, p 603.

Author's biography



Bjorn Brandstedt is an electronics engineer in the avionics department at McDonnell-Douglas, St. Louis, MO. He is responsible for acceptance test procedures for subcontracted components. Prior to this, Bjorn had a stint in the Army and worked at the Boeing Co. Acoustics Laboratory. He received his BSEE from Northrop Institute of Technology and was an EDN Design Award Contest monthly winner.



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- Paper, ceramic tube, epoxy end fill (Type PCE)
- Mylar, impregnated, dipped (Type MDR)
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CHECK NO. 47

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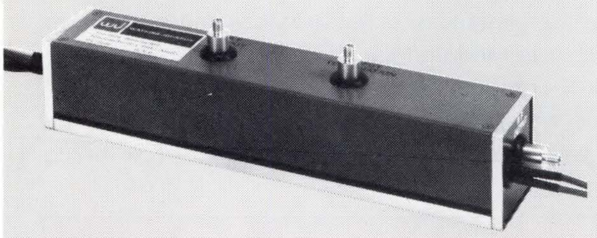

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CHECK NO. 48

Gene Carter of National Semiconductor speaks out

on the pROM as a design tool

The rise in pROM applications has been rapid, and the proliferation of available devices has made the designer's selection task more challenging.

No one will argue the fact that pROMs, or field-programmable ROMs, have made an impact on system logic design. In order to evaluate this impact, one must first understand the rise of the ROM (Read-Only Memory) as a design tool.

First introduced in 1967 as a 256-bit MOS device, the ROM was touted as the answer to all problems associated with look-up tables and code converters. It was offered for sale at about 10¢/bit. Engineers weren't too impressed with this kind of storage then, but felt that if technology could achieve 1024 bits of storage per package, this would be of sufficient capacity and cost to be useful.

The 1024-bit design followed the 256-bit device by about 6 months and began finding interest. One of the first applications was as a character generator for a thermal printer. This gave rise to character-generator and fixed-program micro-instruction sets for data-terminal applications. But the first large-scale application for the ROM did not occur until 1969. Since then, the worldwide volume of ROM sales has grown from 1000 to 2000 units/month to 200,000 MOS and 40,000 bipolar units/month.

ROMs were fine design tools when they were first introduced but they also had their shortcomings—it took 10 to 12 weeks typically for turn-around time to customize the memory pattern. Because the artwork was generated manually, it was prone to at least one error per iteration. To get around objectionable lengthy lead times, development programs to build an electrically alterable memory began during 1968 to 1969.

Long memory **write** cycle times were acceptable but short **read** cycle times were desirable, hence the name read-mostly memory (RMM) was coined. A successful RMM was first achieved in 1971 when a 2048-bit MOS ROM that could be programmed in the field and also be erased and reprogrammed was manufactured.

In the meantime, the engineering community had found the benefits of using ROMs as micro-program storage and random logic elements in processor sections of computer systems. Again, since the micro-instruction set was the last to be specified, but the first part required to prove breadboard feasibility,

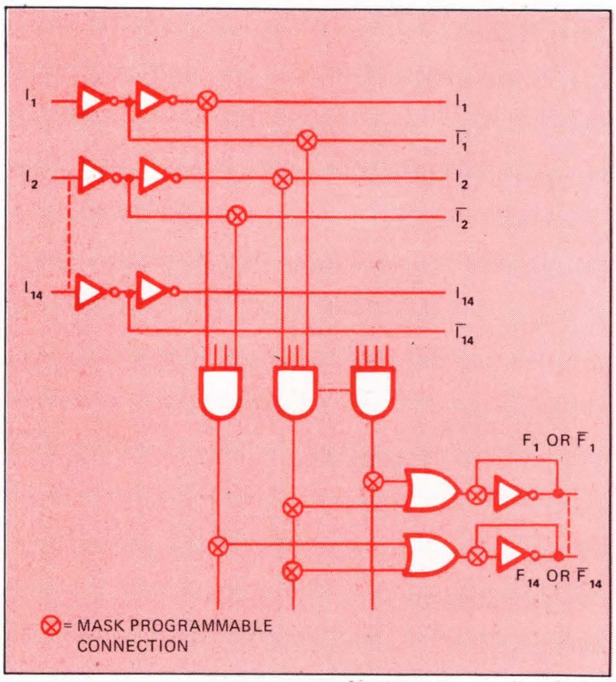


Fig 1—A programmable logic array implements random logic functions. Each output is a Boolean function of any or all the 14 inputs shown, in the form: $F_x = (I_1\bar{I}_2\bar{I}_7I_{14}, + I_1I_3\bar{I}_7$ . . . etc. The maximum number of product terms is 96 and the product may appear in any of the 8 output functions, either inverted or non-inverted.

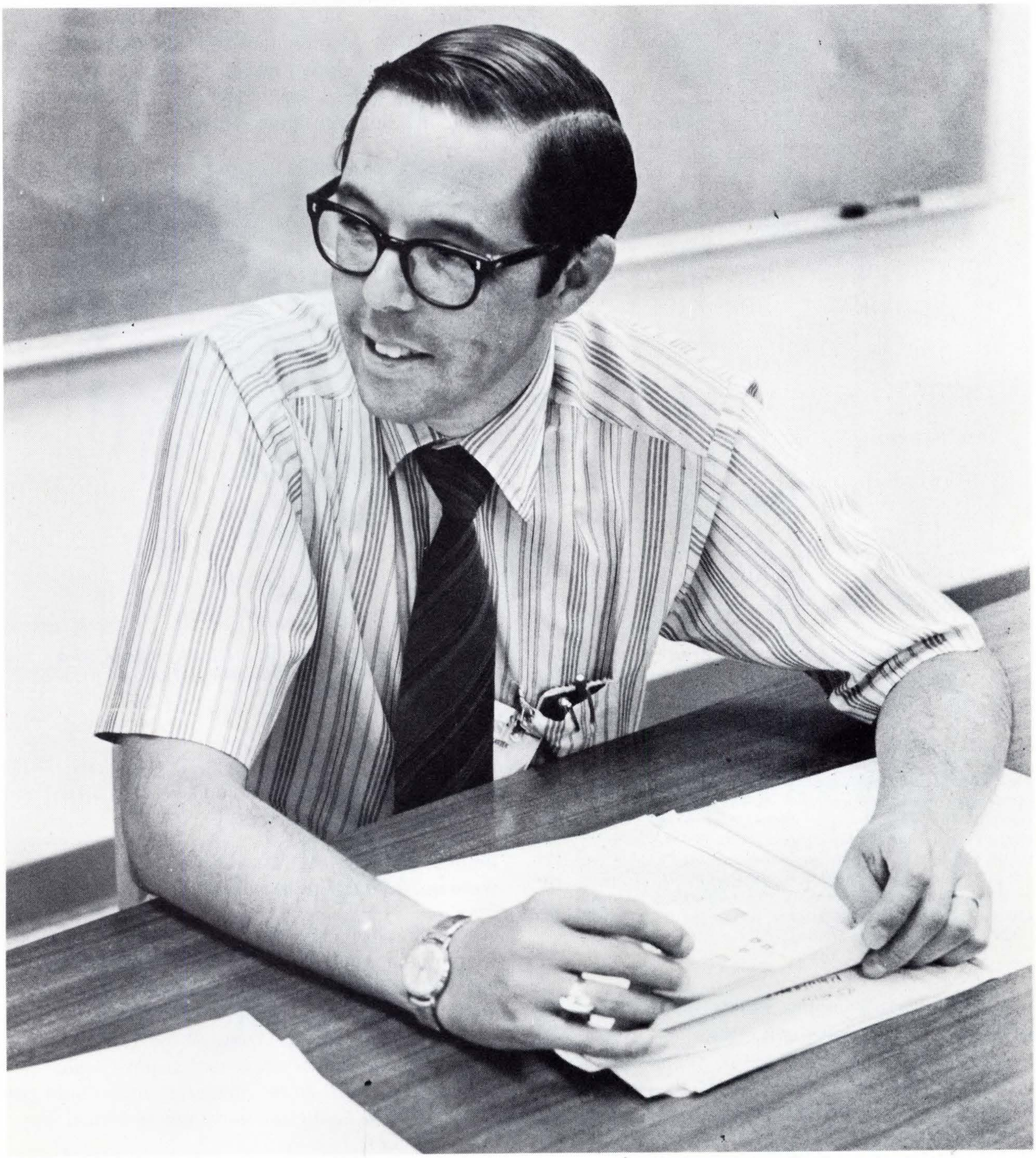
time was of essence.

By this time, automated mask-generation techniques and better production procedures had reduced ROM turn-around times from the usual 10 to 12 weeks down to 5 to 6 weeks—a great improvement, but still too long for impatient designers. Enter the field-programmable ROM or pROM.

The first pROM was a bipolar fusible-link device, only 256 bits in storage capacity, but programmable by the customer. Prices were 25 to 30¢/bit and reliability was questionable since a high current was passed through a nichrome "fuse" that vaporized. But the engineer didn't care. He was using it for prototype development. The big problem was when he made one mistake in programming, he had to throw away a $50 part.

High unit costs and limited storage capacities kept the market from expanding too fast. Bipolar programming techniques such as metal migration were tried to reduce memory cell size and increase storage capacity. It was concluded that for large-capacity pROMs (1024 bits and higher), nichrome fusible links were best for bipolar devices, and trapped-charge floating gates best for MOS devices.

To summarize, all the engineer wanted was a pROM. But as with all IC devices, the number of bits/chip, or storage density, and the number of packages sold were strong factors in reducing unit costs.



Gene Carter is marketing manager—microcircuits for National Semiconductor, Santa Clara, CA. Gene was previously employed at Fairchild Semiconductor. He graduated from the Milwaukee School of Engineering.

The development of a lower-cost mask-programmable (at the factory) device in both MOS and bipolar technologies became essential to reduce production costs on high-volume production runs.

What was needed were bipolar and MOS pROMs that were pin and performance-compatible with mask-programmable ROMs.

A designer could order a few pROMs for field evaluations and then implement production orders

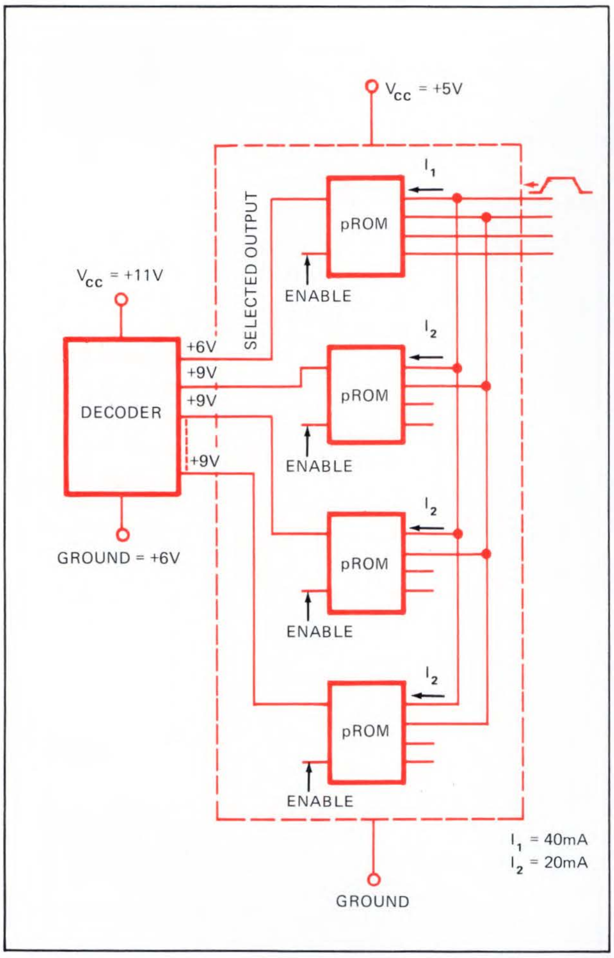


Fig 2—Board programming of pROMs is accomplished by using a decoder to select the appropriate pROM when it (the decoder) is operated at voltage levels 6V higher than normal. The decoder outputs range from 6V for a logic "0" to 9V for a logic "1". Because the decoder outputs are active-low, the "enable" input of the pROM to be programmed is operated at 6V. The other "enable" inputs reach 9V, normally a prohibited level. However, in this case the circuit was designed to use the 9V to prevent the outputs from being programmed.

with mask-programmable ROMs once the circuit design was set, at lower unit costs.

Today, substantial quantities of pROMs are being used to implement random logic, develop breadboards for micro-programs, make field changes to existing equipment and satisfy low-quantity equipment runs. Inventory costs are reduced by the stocking of blank pROMs, rather than 8 or 10 units each of 50 to 100 different ROM patterns.

Implementing random logic is an interesting application. Any black-box logic function that can be written in truth-table form (which includes virtually every function, random and sequential) can be implemented in a ROM or pROM. Now we have a new application for ROMs.

After the concept was accepted, a major drawback was encountered; not enough input variables. Normally, the minterms required to perform the random logic was limited to 50 or 60, but the number of inputs to the black box were more than 9 or 10.

From this evolved another dimension in ROM/pROM development—the Programmed Logic Array (PLA) as shown in **Fig. 1**. With 14 input lines and 8 output lines, logic functions with less than 96 minterms, but with greater than 10 input variables,

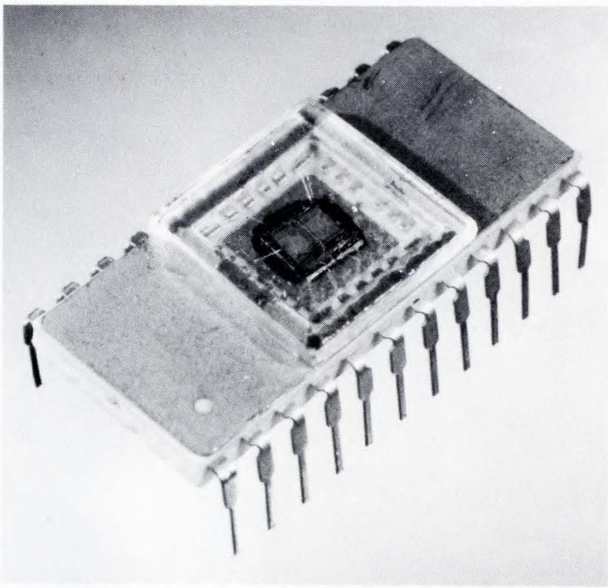


Fig. 3—An MOS pROM has the added advantage of being erased with ultra-violet light and reprogrammed. However, it is about 10 times slower than a bipolar pROM.

can be implemented in a single PLA package. Typically, this one package will replace 20 to 30 SSI and MSI discrete logic packages.

Bipolar pROMs are fast devices, but early ones were questionable as to reliability.

Now that necessity has invented the part most desired by the engineer, features and benefits become the next criteria for product selection. A pROM is manufactured with an "all 1"s condition in the truth table and the customer "blows" the fusible link at the appropriate bit locations to provide a logic "0". Another drawback arose. Since the array could not be tested, how could one guarantee electrical integrity of the part?

The fusible-link characteristics were easy to guarantee by merely putting a test fuse on the die that is programmed at the vendor's factory. The nichrome deposition across a wafer is very uniform, hence that's no problem. The problem was to guarantee the non-functionality of the pROM due to random defects in the silicon, or in the metalization on the die. How did the customer know that all the devices he ordered would work . . . or 60% of them . . . or 10% of them? It was simply blind faith and necessity.

Today, the decoding logic can be exercised to insure its functionality and also to allow testing both logic "1" and "0" output levels under rated loading conditions. One way of doing this is to apply a 9V signal to the most significant address pin and verify that all outputs go to a logic "0" under the specified load conditions.

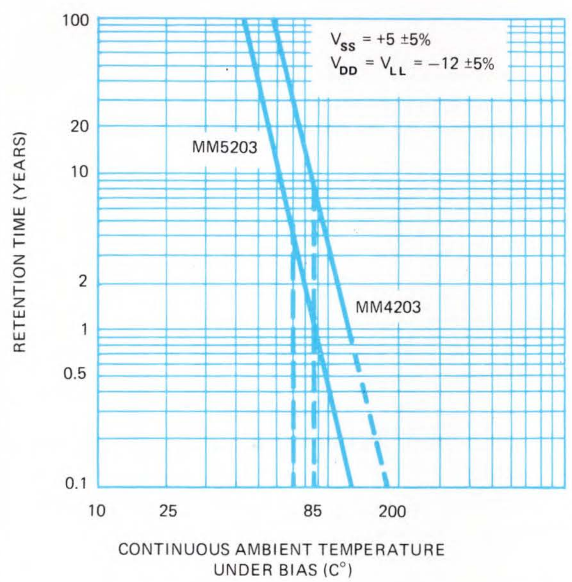


Fig. 4 — MOS pROMs have retention capabilities influenced by time and temperature. This retention time is shown as a function of temperature for two popular MOS pROMs on the market — National Semiconductor's MM4203Q/MM5203Q.

The ability to do this testing has increased the reliability of a pROM to the customer by: eliminating malfunctioning devices due to random defects in the silicon substrate, verifying the ability to program the fusible link, and by eliminating field failures due to infant mortality through proper testing. All of these benefits minimize the field rework necessary and reduce the high cost of field servicing.

Open collector or Tri-State? The choice clearly depends on the application's required speed.

Most applications require 2 to 8k bits of memory, and multiple pROM packages are needed to satisfy a given function. As a result, two additional benefits were needed to facilitate this: board programmability and Tri-State logic outputs.

The board programmability aspect adds flexibility to the use of pROMs. Previously, it was not possible to program pROMs soldered into boards because the possibility of a defective part due to testing limitations made rework highly probable. It was also not possible because "OR" tied outputs prevented the application of a program pulse to only one package at a time.

Board programming can be implemented using a separate decoder that selects the appropriate pROM (**Fig. 2**). Standard memory cards, unprogrammed, can then be inventoried for system manufacture or field servicing to improve production-line flow and reduce field-service turn-around time.

Open-collector outputs allow "OR"ing of multiple pROM packages, but require the use of an external resistor. But the speed of a system is a function of the external resistance and the amount of capacitance associated with the output line, and this tends to slow down system speed. Most recent processor applications make use of data bussing by using a common bus system structure. Since pROMs with Tri-State logic outputs allow a common bus system structure, improved system speed without external components can result.

TABLE I — OPEN-COLLECTOR VS TRI-STATE

Parameter	Open-Collector	Tri-State
Memory access time	50nsec	50nsec
Memory to ALU bus Delay	150nsec	18nsec
ALU delay	36nsec	36nsec
ALU to memory delay	10nsec	10nsec
Memory write time	30nsec	30nsec
Total time	**276nsec**	**144nsec**

This is important since pROMs used in CPUs require the maximum obtainable speed. Tri-State logic output has a dynamic current capability of 40 mA to charge the line capacitance in addition to its static current capability of 16 mA. Also, the third state is a high-impedance state that looks like a current load of no more than 40 μA. An example comparison of speed improvement for open-collector vs Tri-State logic is shown in **Table 1** using an add cycle.

MOS pROMs fill a similar but different function from bipolar ones.

The speed of an MOS pROM is a factor of 10 slower than the bipolar pROM, so it is most useful in

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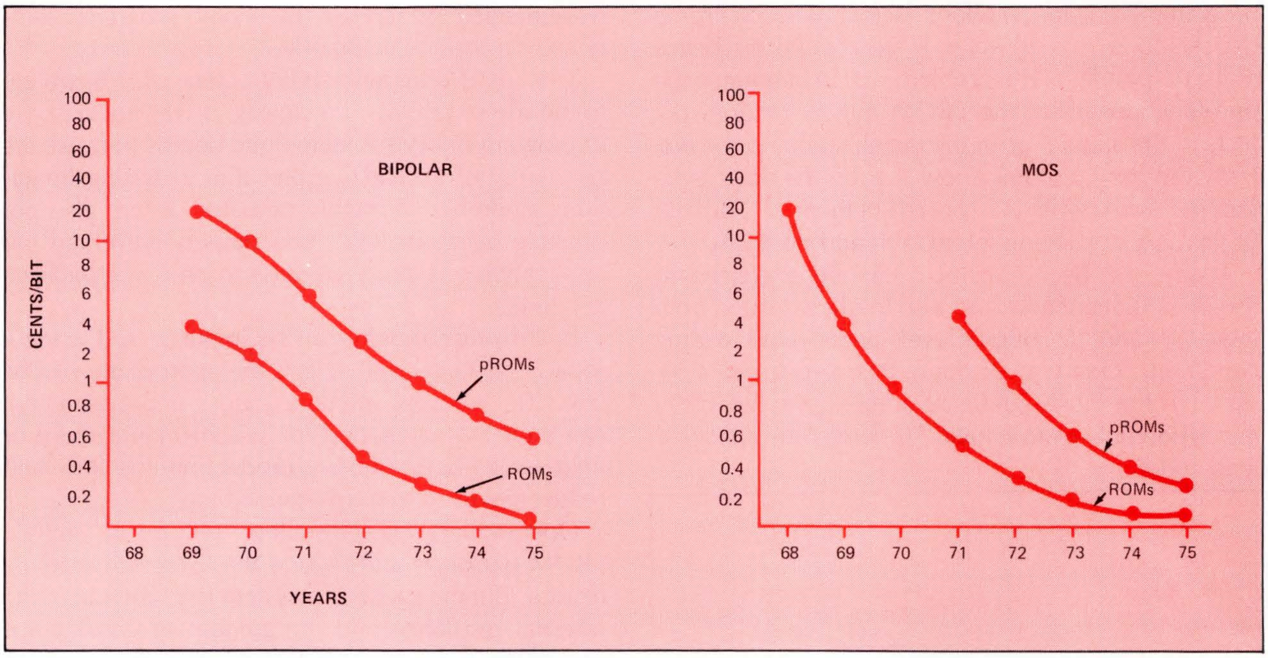

Fig 5—The price/bit for both bipolar and MOS pROMs has come down to less than 1¢/bit and continues to go down. MOS pROMs should cost about 0.3¢/bit compared to 0.6¢/bit for bipolar pROMs, by 1975, closely approaching the price/bit of ROMs.

systems with a man-machine interface. In addition to being programmable, it has the added feature of being erasable (see **Fig. 3**) and reprogrammable. MOS pROMS are packaged with a quartz lid so that the memory chip can be exposed to ultra-violet light, which releases the trapped charge that is stored in the chip. The memory is then returned to an all "1"'s condition. It can then be reprogrammed with the correct information.

From an economic standpoint, the erasable MOS pROM has the advantage over a non-erasable bipolar pROM. If one programs a $30 fusible-link bipolar pROM improperly, it must be discarded and another $30 pROM purchased.

On the other hand, for a $50 erasable MOS pROM, the cost is $25/function at the first mistake, and $16.67 at the second mistake. And it can be reprogrammed 4 or 5 times without causing degradation in device characteristics.

The retention capability of the MOS pROM is important since it utilizes a trapped-charge phenomena whose retentivity is a function of time and temperature, For example, National's MM4203Q/-MM5203Q MOS pROM has a guaranteed lifetime at any given temperature (graph of retentivity vs temperature shown in **Fig. 4**) of 5 years at +70°C. However, in a use environment, the temperature will vary somewhat over the years. By summing the amount of time (Y_t) at a given temperature and dividing each by the lifetime at that temperature (L_x), a true lifetime can be determined as shown below.

$$\text{True lifetime} = \sum_{t=-55°C}^{t=+125°C} \frac{Y_t}{L_t}$$

where

$$Y_t = y_a + y_b + y_c \ldots \text{etc.}$$

$$\frac{1}{L_t} = \frac{1}{l_a} + \frac{1}{l_b} + \frac{1}{l_c} \ldots \text{etc.}$$

and

y_a = per cent of lifetime at a given constant temperature

l_a = lifetime in years at a given constant temperature

The use of these equations can establish a more realistic picture of a pROM lifetime. If the pROM is reprogrammed at any time during the lifetime, the full useful life is re-established and a new lifetime calculation can be made.

The MOS pROM also has all of the features of the bipolar pROM: pin compatibility with a mask-programmable ROM, Tri-State outputs, in-process testing capability and a method of board programming.

As in the past, requirements for ROMs and pROMs will continue to push the state-of-the-art in circuit design and technology. Lower-power pROMs will appear in the next 12 to 18 months. Bigger bipolar pROMs are already coming out. It seems that field-programmable PLAs have to be the next logical step. Speed improvements through circuit design and new processing will enhance pROM features as well.

CMOS logic families are also coming into their own. Some are pin and voltage compatible with the 54/74 bipolar IC family. This makes programmable PLAs or pROMs a logical step in future products. □

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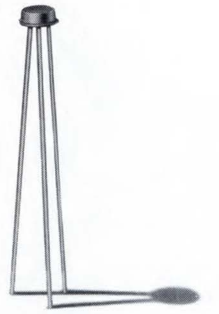

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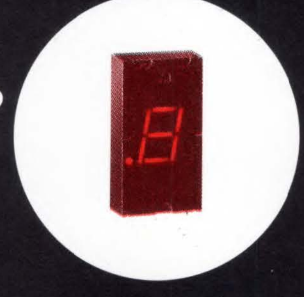

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CHECK NO. 53

EDN DESIGN AWARDS

Clocked square-wave generator uses CMOS

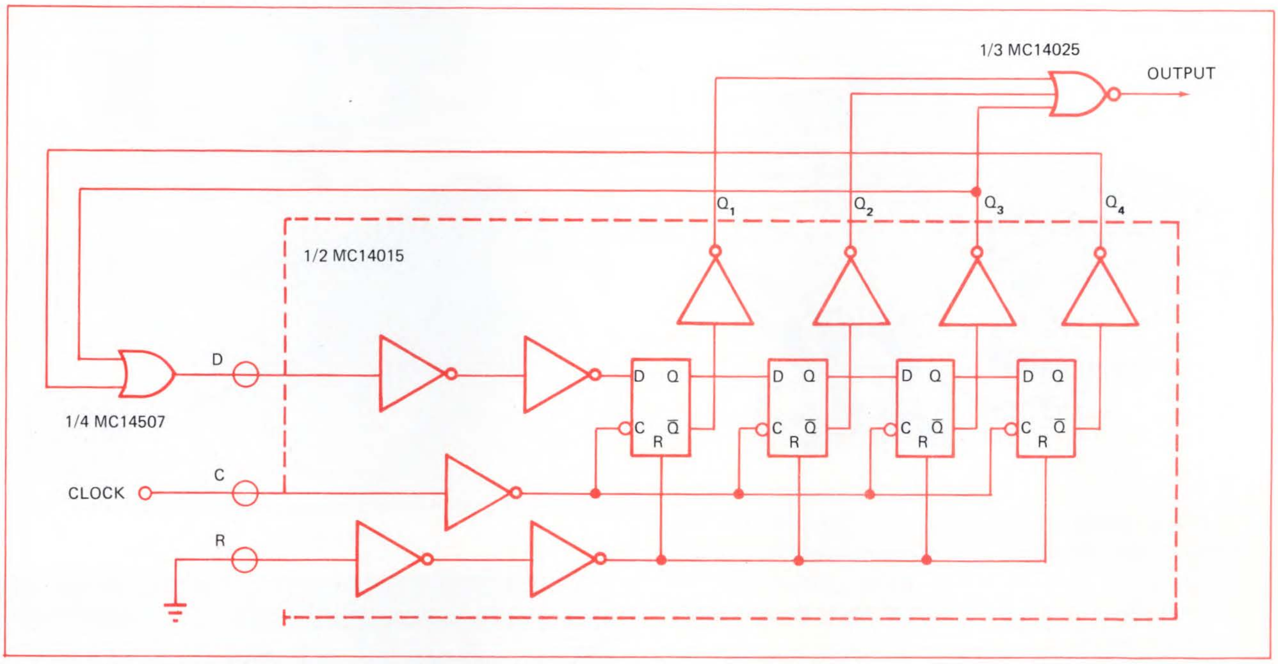

Fig. 1—A 15-state pseudorandom sequence generator using the required number of flip-flops from a CMOS shift register is decoded to provide a 1/15 output pulse.

Earl Carlow
Motorola, Inc., Phoenix, AZ

A shift register (1/2 of the MC14015) is the heart of this square-wave generator. Using additional logic provides an output of differing duty cycles. The basic circuit, shown in **Fig. 1**, provides a duty cycle of 1/15.

The shift counter, a shift register with feedback, uses part of 2 ICs (1/2 MC14015 and 1/4 MC14507). This counter is incremented with an input clock pulse, and the register package reset input, R, is tied to gsround. The count cycle of this counter has a maximum length of $2^n -1$ states. With 4 flip-flops (n=4) the cycle, or the full square wave, is 15 counts long. The count state sequence for

TABLE I – STATE SEQUENCE FOR A 1/15 DUTY CYCLE

State	Q_1	Q_2	Q_3	Q_4	D	Output
1	1	0	0	0	0	0
2	0	1	0	0	0	0
3	0	0	1	0	1	0
4	1	0	0	1	1	0
5	1	1	0	0	0	0
6	0	1	1	0	1	0
7	1	0	1	1	0	0
8	0	1	0	1	1	0
9	1	0	1	0	1	0
10	1	1	0	1	1	0
11	1	1	1	0	1	0
12	1	1	1	1	0	0
13	0	1	1	1	0	0
14	0	0	1	1	0	0
15	0	0	0	1	1	1 (Decode)
1	1	0	0	0	0	0

TABLE II – STATE SEQUENCE FOR A 50/50 DUTY CYCLE

State	Q_1	Q_2	Q_3	Q_4	D	Output
1	1	0	0	0	0	0
2	0	1	0	0	0	0
3	0	0	1	0	1	0
4	1	0	0	1	1	0
5	1	1	0	0	0	0
6	0	1	1	0	1	0
7	1	0	1	1	0	0
8	0	1	0	1	1	1
9	1	0	1	0	1	1
10	1	1	0	1	1	1
11	1	1	1	0	1	1
12	1	1	1	1	0	1
13	0	1	1	1	0	1
14	0	0	1	1	0	1
15	0	0	0	1	1	1/0
1	1	0	0	0	0	0

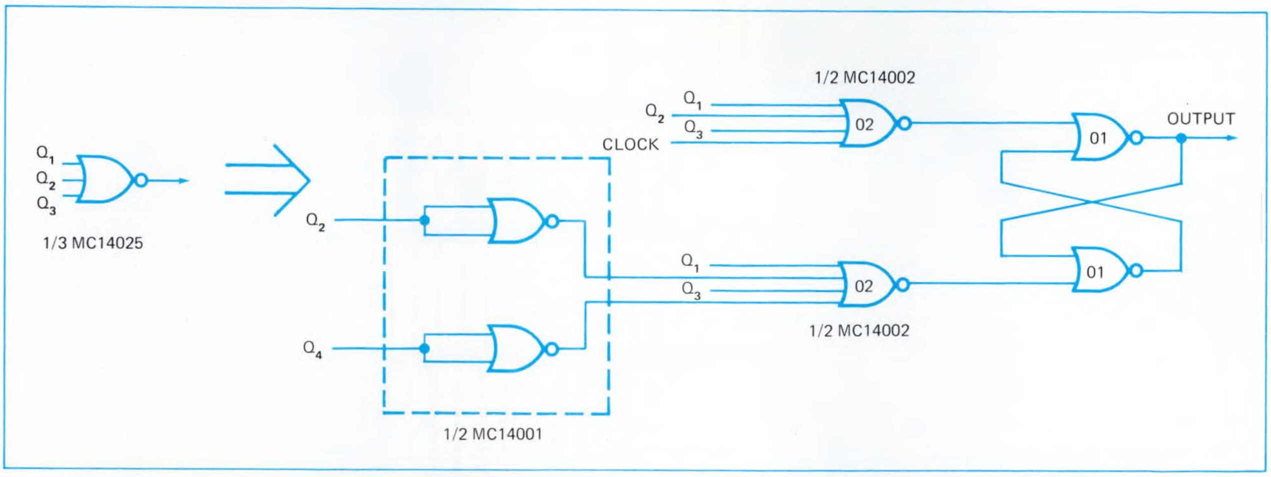

Fig. 2—Square wave logic, to the right,.can be used in place of the 3-input NOR decoder in **Fig. 1** to provide a 50% duty cycle output.

this counter is shown in **Table I** which provides a 1/15 duty cycle square-wave output.

Since the shift register counter is synchronous, all of the outputs change synchronously. This means "glitch-less" cedocing of the signal at the output.

If a 50% duty cycle output square wave is desired for the odd number of states (15/2 = 7.5 states), the output logic can be changed. For example, this can be done **as shown in Fig. 2** by replacing the 3-input NOR gate on the output of the basic circuit with 2 other logic ICs and utilizing the input clock logic ICs. After this change the circuit operates as a 50% (7.5/7.5) duty cycle square-wave generator. The sequence states for this 50% duty cycle circuit as shown in **Table II**. If a different duty cycle output is desired, a different decode can be selected in place of state 15.

This circuit, then, converts a clock input to any length/duty-cycle square wave desired for your application. A similar circuit technique can be implemented using any other odd-state synchronous counter. □

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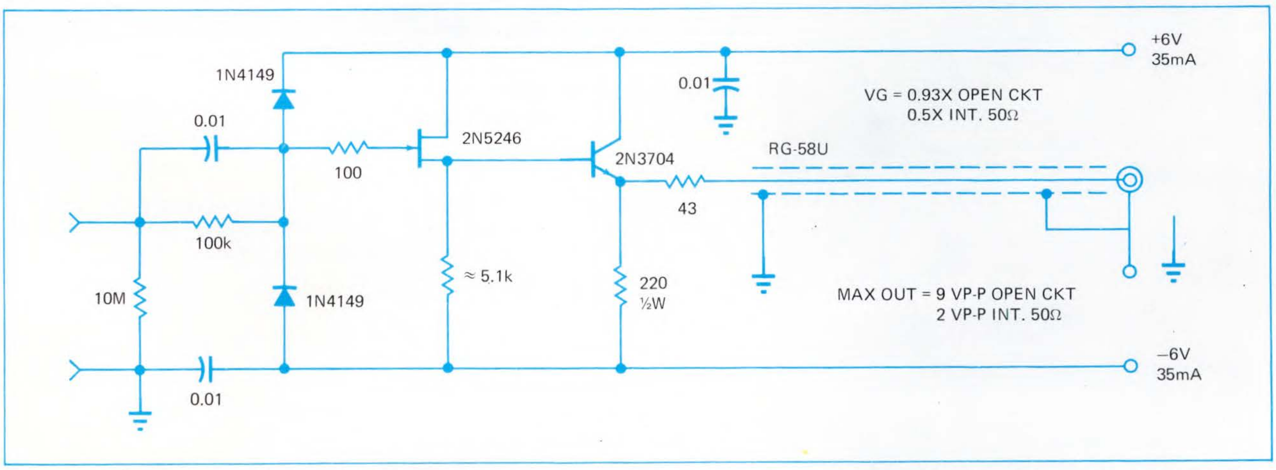
Long Island City, NY

This impedance converter probe was originally designed to drive the 50Ω input of a spectrum analyzer but has since been used with ac voltmeters, video amplifiers, frequency counters and



Impedance converter exhibits 10 MΩ input and 50 Ω output with a voltage gain of precisely 0.5. It was designed to drive test equipment.

other devices which cannot use an ordinary scope probe to minimize loading.

As shown, the probe has an input impedance of 10 MΩ shunted by 8 pF. Eliminating the protective diodes reduces this to about 4 pF. The frequency response of the probe extends from dc to 20 MHz (−1 dB), although higher frequency operation is possible through optimized construction and use of a UHF-type transistor.

Zero dc offset at the output is achieved by selecting a combination of a 2N5246 and source resistor that yields a gate-source bias equal to the V_{be} of the 2N3704 (approximately 0.6V).

At medium frequencies, the probe can be used unterminated for near-unity gain, although for optimum high-frequency response, the cable must be terminated into 50Ω. If a 75Ω system is desired, use a 62Ω output resistor and Belden 8218 cable. In either case, the voltage gain when properly terminated is precisely 0.5X.

By using miniature parts and careful construction, this circuit can be neatly and conveniently packaged in an aluminum cigar tube. The input end of the probe is fitted with a 6-32 threaded stud, so Tektronix probe tip accessories can be used. □

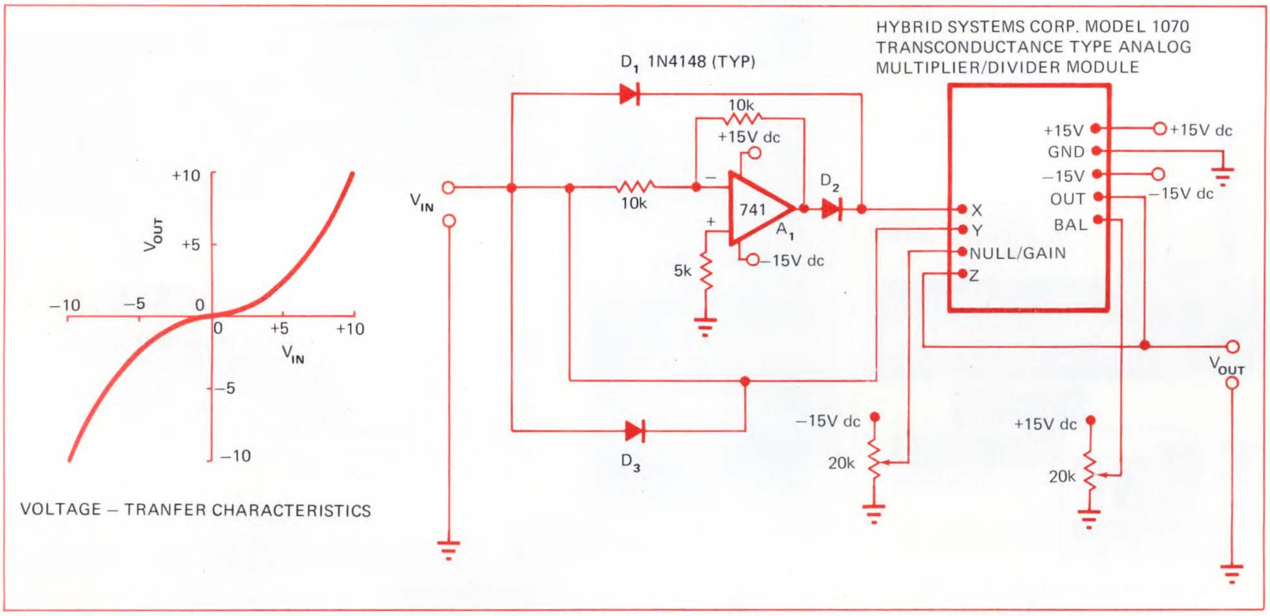
To Vote for This Circuit
Check 151

Diodes provide switching and isolation for absquare circuit

William R. McWhirter, Jr.
Naval Ship Research and Development Center, Annapolis, MD

The absolute-value-squaring (absquare) circuit provides the designer with a peculiar and useful nonlinear function. The circuit voltage-transfer characteristic is $V_{out} = +V_{in}/V_{in}/10$. Using a few diodes, resistors, an op amp and a general purpose multiplier, a circuit designer can closely approximate a fairly complex function which has been available only on the more modern analog and hybrid computers. The outstanding feature of this circuit is that it uses common, inexpensive components comprising a relatively simple circuit with the tradeoff being the loss of computer-level accuracy.

In circuit operation, diodes D_1 and D_2 act as switches to assure that only absolute values of V_{in},$/V_{in}/$, are seen at the X terminal of the multiplier. Op amp A_1 acts as the inverter for negative V_{in} values. The amplifier input and feedback resistors should be, at least, good commercial grade types. The Y terminal is permitted to see the actual value of V_{in}; so that the appropriate polarity will be observed at the output of multiplier/divider module. Diode D_3, along with D_1 and D_2, provides circuit isolation so that improper signals cannot stray back to the input signal source, V_{in}, while main-



Absquare circuit provides valuable simulation of mechanical system responses with approximately 2% accuracy.

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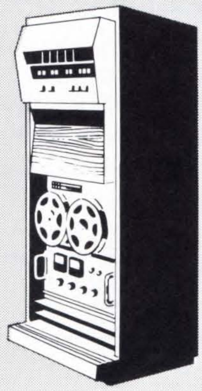

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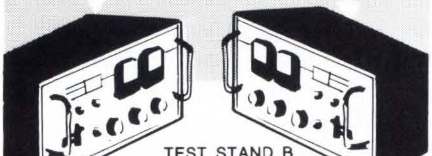
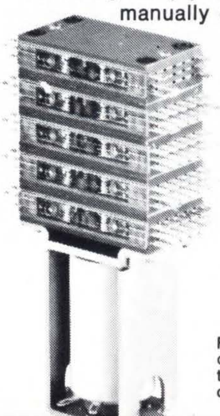


T-Bars are designed specifically for switching many parallel lines either manually or remotely.



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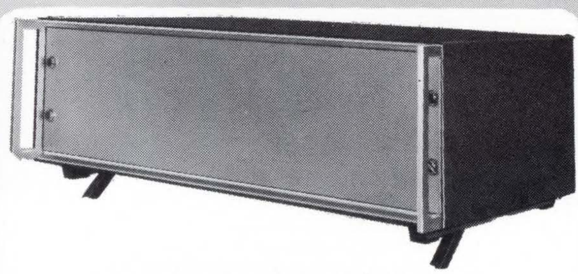

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CHECK NO. 58

taining desired transfer characteristic integrity.

The Hybrid Systems Corp. multiplier/divider module (Model 107C) was chosen because its output characteristic is +XY/10. However, any type multiplier/divider circuit may be selected as long as the proper (and desired) output polarity is observed.

As was stated previously, this circuit can easily be applied if analog and hybrid computer accuracy is not necessary. However, if external "null/gain" and "balance" trimmer potentiometers are used, then ±2% full scale, 4-quadrant accuracy can be achieved. Adjusting these trimmers can help to compensate for the distortion in the voltage-transfer characteristic caused by the diodes forward-voltage drop.

The absquare circuit is particularly useful in simulation and control circuits for continuous, real-time, mechanical systems. One of its more common applications is simulating hydraulic servo valve multiple-flow-gain; as the circuit transfer characteristic closely approximates the nonlinear relationship that can exist between servo valve main-stage spool displacement and valve main-stage output flow. The circuit can provide convenient intentionally nonlinear control for linear-type systems. □

To Vote For This Circuit
Check 152

Use opto-isolation in your next video amp

Dave Weigand
Gulf & Western Research, Swartmore, PA

Often a low-frequency (AGC) gain control or multiplier function is required in a video amplifier. The standard technique is a JFET/resistor voltage-divider circuit similar to the one shown in **Fig. 1.** This works fine for low-level video inputs up to 100 mV or so, but not for high dynamic range video inputs of up to 10V. The FET resistance becomes a function of the input signal voltage level, as well as the AGC gate voltage.

The circuit in **Fig. 2** (Hark, the old Raysistor) replaces the JFET with a photocell/LED combination. Due to the linear resistance of the photocell, the video amplifier gain is not effected by input signal dynamic voltage swing, or by frequencies to 20 MHz. Only direct AGC input-voltage controls the amplifier gain. □

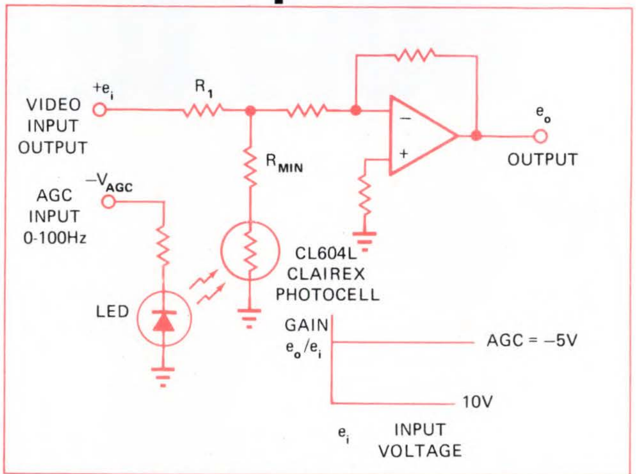

Fig. 2—An LED, used within its linear range of light output vs current input, and a photocell eliminate the interaction of input signal and AGC voltage.

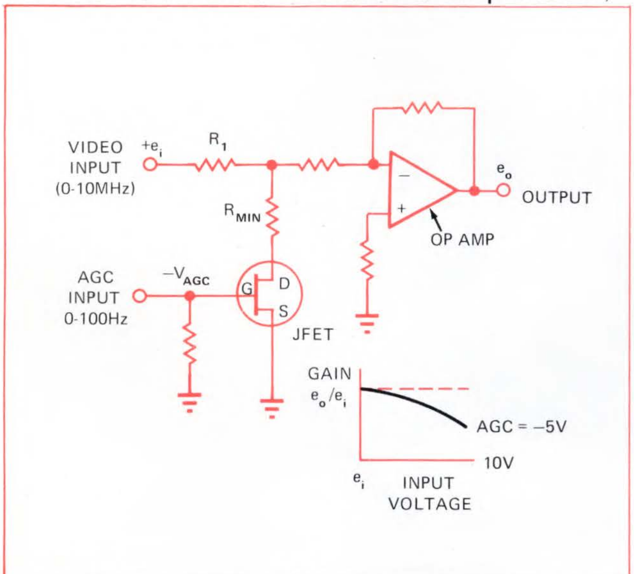

Fig. 1—Conventional JFET-AGC circuit is susceptible to variations of R_{ON} for the FET caused by the applied drain-to-source (signal) voltage.

To Vote For This Circuit
Check 153

Readers have voted:

George Smith winner of the September 1st Savings Bond Award. His winning circuit is "Novel clock circuit provides multiplexed display". Mr. Smith is with Litronix, Inc., Cupertino, CA.

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Rms-to-dc converter module rivals bench instrument performance

PROGRESS IN CIRCUIT MODULES

If you need an accurate measurement of ac signals, you probably need rms measurement. Although average-responding voltmeters generally have ac ranges that are calibrated in rms volts, those measurements are valid only for undistorted sine waves. Therefore, measurement of the value of SCR waveforms, pulse trains, triangle waves or sine waves with harmonic distortion taken on an average-responding instrument could be grossly in error.

Within the past year and a half, several manufacturers have come out with converters based on operational circuitry, whereas the traditional approach is based on some type of thermal sensor.

How rms-dc converters work

The true rms value of a voltage is defined as:

$$V_{rms} = \sqrt{\frac{1}{T}\int_o^T (V_{in})^2\, dt}$$

In most rms measurements we are interested in a continuous reading of rms level, so we make the time interval T very long. The average value of $(V_{in})^2$ is obtained by low-pass filtering. This provides a "running average" and is therefore a continuous measure of the rms level.

The time constant of the low-pass filter must be large relative to the lowest frequency of interest for proper averaging. The squaring and division operations are accomplished through nonlinear operational circuitry.

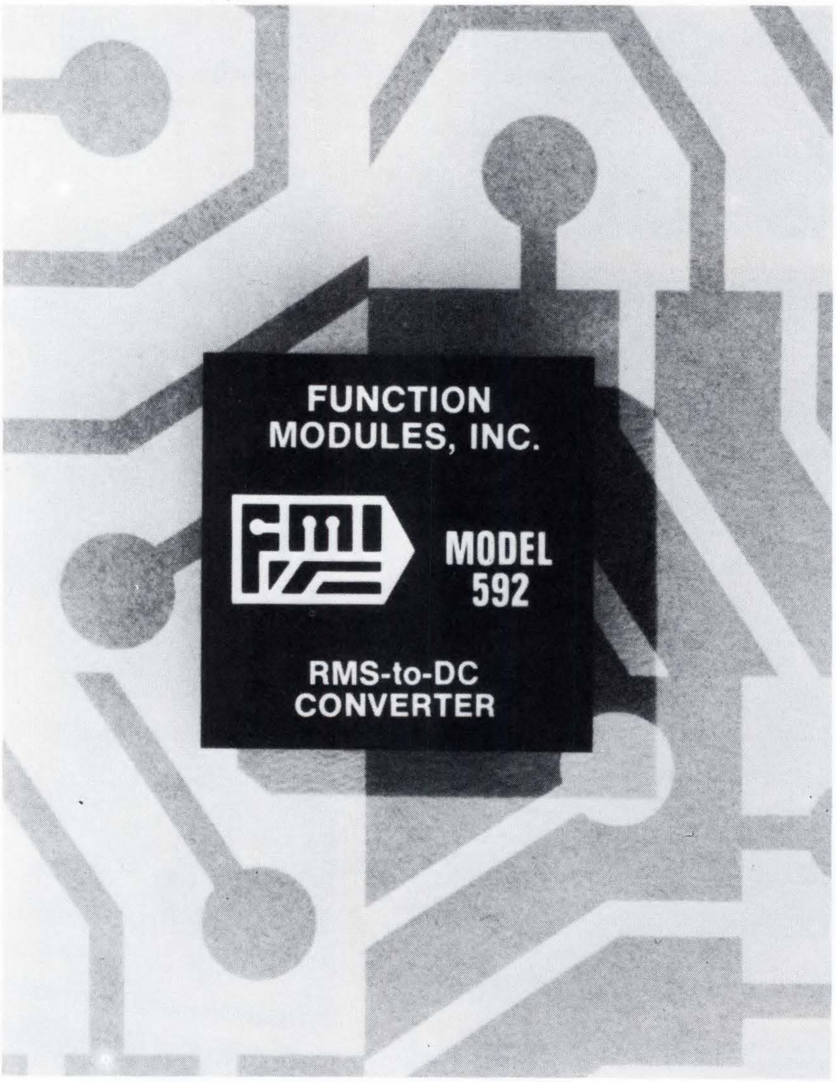


Fig. 1—Operational rms-to-dc converter module combines low-pass filtering and nonlinear operational circuitry to accurately measure rms voltage.

One of the newest entries in this field of operational converters is a circuit in a module package from Function Modules, Inc. (**Fig. 1**) that is claimed to rival bench instrument performance. Designed for OEM use in test instruments or for incorporation into special instrumentation systems, the Model 592 has an accuracy of ±0.1% of input ±0.03% of full scale (full

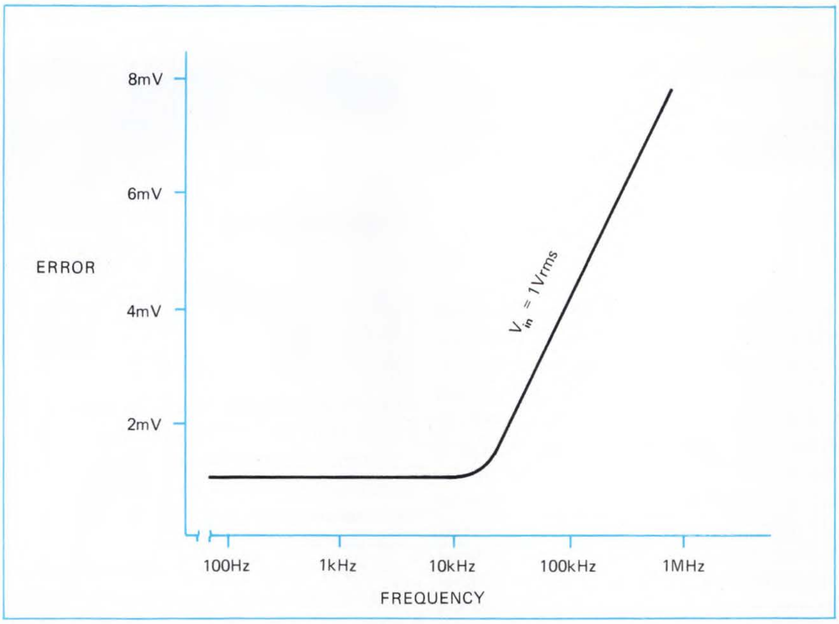


Fig. 2—Output error varies as shown with changes in input frequency for a 1V rms input signal.

scale = 1V rms) over an input range of 10 mV to 1V rms and a frequency range of 50 Hz to 10 kHz.

As shown in **Fig. 2,** error increases as frequency goes up, but at 100 kHz, the accuracy is still claimed to be ±0.5% of input ±0.5% of full scale. Crest-factor spec is 7 at full scale. **Fig. 3** shows a typical curve of error vs. crest factor for a pulse train using the Model 592.

Other pertinent specs for the converter are: 2.5-kΩ input and 1Ω output impedance, power supply requirements of ±14V to ±16V and a quiescent drain of ±10 mA. The module measures 2 in. square by 0.40 in. high. Cost is $115 in single quantity.

Function Modules, Inc., 2441 Campus Dr., Irvine, CA 92664. Phone(714)833-8314. **280**

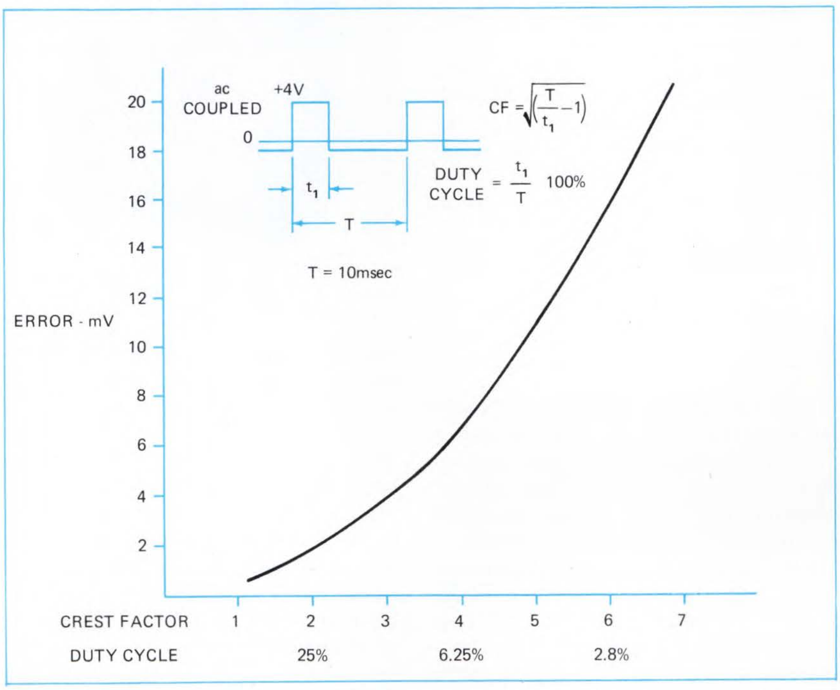
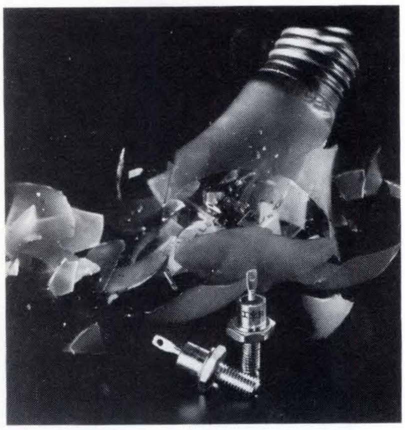
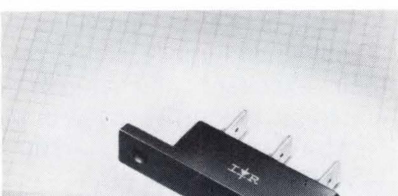


Fig. 3—Crest-factor capability is demonstrated for a pulse train. Output error for a 3% duty cycle is about 2%.



HIGH VOLTAGE RECTIFIERS BOAST FAST RECOVERY. Three series of 12A types 12FL, 12FT and 12FV have maximum repetitive peak reverse voltage ratings through 1000V and feature an improved soft recovery characteristic, reducing self generated voltage transients. Maximum reverse recovery time is 200 nsec for the 12 FL series, 350 nsec for the 12FT series and 500 nsec for the 12FV series. All types have a maximum peak one cycle non-recurrent surge current rating of 150A. Prices in 1-99 quantities are $15 for the 12FL100, $17.25 for the 12FT100 and $19.80 for the 12FV100. International Rectifier Corp., Semiconductor Div., 233 Kansas St., El Segundo, CA 90245. Phone(213)678-6281. **170**

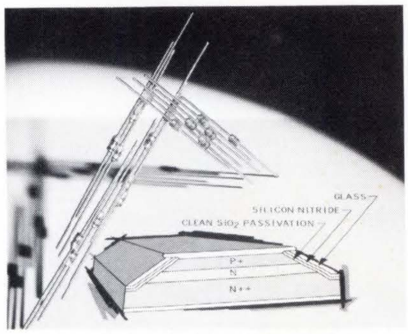


CENTER-TAP RECTIFIERS HAVE EXCELLENT RANGE RATINGS. Series 150 VC (positive) and 150 VJ (negative) centertaps are rated for operation at 15A and series 300 WC (positive) and 300 WJ (negative) are rated for 30A at a case temperature of 75°C. The 15A series features a maximum peak one-cycle, non-repetitive surge current of 150A, while the 30A series features 400A surge ratings. Chief applications are in battery chargers and computer power supplies. Both are packaged in molded circuit assemblies, and may be specified for maximum repetitive peak reverse voltage ranging from 100 to 1000V. International Rectifier Corp., Semiconductor Div., El Segundo, CA 90245. Phone(213)820-2606. **171**

ICs PROVIDE SPEED REGULATION FOR SMALL MOTOR. Designated TCA600 and TCA610, these linear ICs are intended specifically for record player, tape recorder and cassette motors. The TCA600 is suitable for battery operated portable equipment and the TCA610 for car battery and line operations. Compared with discrete component solutions, the following advantages are obtained: Higher electrical and mechanical reliability; high thermal stability; higher current supplied at low temperatures during switch-on making motor starting easier. Both the TCA600 and TCA610 are mounted in TO-39, 3-lead metal cans. Price for either in 100-999 qtys. is $2.00. SGS-ATES Semiconductor Corp., 435 Newtonville Ave., Newtonville, MA 02160. Phone(617)969-1610. **172**

TUNING VARACTORS FEATURE ULTRA LOW LEAKAGE. Typical leakage currents for this series of diodes is 20 nA at 25°C and 500 nA at 150°C, making them ideal for applications requiring excellent frequency or phase stability with temperature variations. This feature is further enhanced by capacitance/temperature coefficients as low as 200 ppm/°C. Specifications for minimum total capacitance tuning ratio range from a low of 3.5:1 to as much as 10.0:1. Three reverse voltage breakdown series are available: 45, 60 or 120V. Minimum Q at −4V varies from 1000 to 2000 in the 45V series; from 800 to 1500 in the 60V series; and from 450 to 500 in the 120V series. Varian, Solid State Div., Salem Rd., Beverly, MA 01915. Phone(617)922-6000. **173**

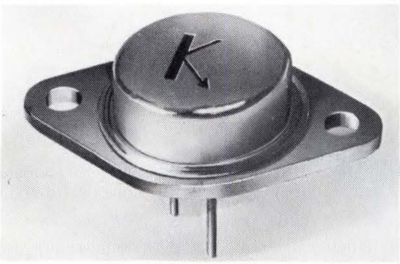
TYPES ULX-2137A and ULX-2137N ARE MONOLITHIC ICs for super-heterodyne am radio applications. Each device contains two amplifiers, a mixer-oscillator, an AGC detector, and a voltage regulator on a single silicon chip. These devices are available in 14-lead plastic DIPs or the 14-lead plastic quad in-line package. Other features are built-in overvoltage protection and separately accessible amplifiers. Sprague Electric Co., Semiconductor Div., 115 Northeast Cutoff, Worcester, MA 01606. Phone(617)853-5000. **174**



RECTIFIER DIODE SERIES IS RATED AT ONE AMP. The devices are designated the 1N4001 through 1N4006. These diodes use double-plug construction that affords integral positive contacts by means of a thermal compression bond. Moisture-free stability is assured through hermetic sealing. The coefficients of thermal expansion of the glass case and the dumet plugs are closely matched to allow extreme temperature excursions. Peak reverse voltage ranges from 50V for the 1N4001, to 800V for the 1N4006, with peak surge current capabilities up to 30A. Texas Instruments Inc., Inquiry Answering Service, P.O. Box 5012, M/S 84, Dallas, TX 75222. Phone(214)238-3741. **175**

POTTED SILICON BRIDGE ASSEMBLIES INTRODUCED. A series of low cost, epoxy encapsulated bridges, type SxP, meet a wide range of environmental conditions and are available in single and three-phase bridge rectifier configurations. Single-phase units are available at current ratings from 3A to 10A at a case temperature of 55°C. The three-phase units are available for current ratings from 3.5A to 10A at 55°C case temperatures. The assemblies are designed to withstand overload currents to 300A. Repetitive voltage ratings are to 1200V. Westcode Semiconductors, 282 Belfield Rd., Rexdale 605, Ontario Canada. **176**

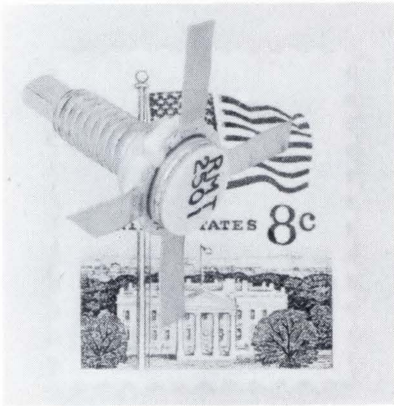
OPTO PRICE REDUCTIONS ARE IMPRESSIVE. Reductions range up to 48% on two phototransistor opto-isolators. The IL-1, with 2500V of isolation and 20% min CTR was reduced from $3.35 to $1.72 in 100 to 999 quantities, and the IL-12, with 1000V of isolation and 2% CTR was reduced from $1.55 to $1.33 in 100 to 999 quantities. The IRL-60, infrared LED, was reduced from $1.10 to $.54 in 100 to 999 quantities. Litronix, 19000 Homestead Rd., Cupertino, CA 95014. Phone(408)257-7910. **177**



COMMERCIAL POWER TRANSISTORS ARE LOW PRICED. These are 2N3055–type transistors designed as an inexpensive solution for meeting rugged application requirements. These NPN silicon transistors designated KD4044 meet or exceed the characteristics of similar plastic power devices now on the market and are similarly priced, although packaged in a hermetically sealed steel TO-3 case. The KD4044 is rated for $BV_{CEO} > 40V$, h_{FE} @ $4.0V/2.0A > 20$ and V_{CE} (sat) @ $2.0A < 1.10V$. Pricing is up to $.30 each in 1000 piece quantities. Kertron Inc., 7516 Central Industrial Dr., Riviera Beach, FL 33404. Phone(305)848-9606. **178**

DARLINGTON ARRAYS DRIVE LED OR INCANDESCENT READOUTS. A series of high-current arrays consist of seven silicon Darlington pairs on a common monolithic substrate. Type ULN-2031A consists of 14 NPN transistors connected to form seven Darlington pairs with NPN action. Type ULN-2032A (h_{fe} = 500 min.) and Type ULN-2033A (h_{fe} = 50 min.) consist of seven NPN and seven PNP transistors connected to form seven Darlington pairs with PNP action. All devices feature a common emitter configuration. These devices are especially suited for interfacing between MOS, TTL, or DTL outputs and 7-segment LED or tungsten filament indicators. Sprague Electric Co., Marshall St., North Adams, MA 01247. Phone(413)664-4411. **179**

SEMICONDUCTORS



PLANAR EPITAXIAL TRANSISTORS FOR MICROWAVE APPLICATIONS. The RMT 1605 and RMT 2501 are primarily for Class A, B, and C, VHF, UFH and microwave amplifier or oscillator applications. The RMT 1605 offers 5W output with 6 dB gain at 1 GHz while the RMT 2501 is rated at 1W output with 5 dB gain at 2 GHz. Both transistors are particularly suitable for use in microwave communications links, ECM, phased-array radar, and L-band telemetry. They are available in hermetically sealed stripline stud packages featuring low inductance leads, which are particularly useful in high frequency circuits as well as in lumped constant circuits. In 1-99 quantitiies, the RMT 1605 is priced at $44 each; the RMT 2501 at $48 each. Raytheon Co., Special Microwave Devices Operation, Wayside Ave., Burlington, MA 01803. Phone(617)-862-6600. **180**

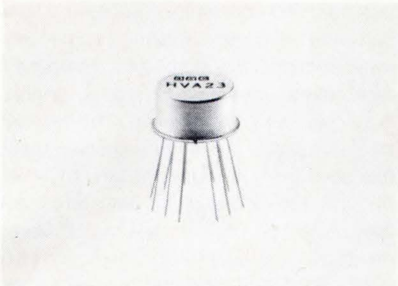
FIVE MORE 54C/74C PARTS ADDED TO CMOS LINE. Each 54/74C part can drive 2 low-power TTL loads. Power dissipation is typically 10 nW per gate. The latest devices added to the line are the 74C42N BCD-to-decimal decoder, 74C95N 4-bit parallel shift register, 74C151N 8-bit multiplexer, 74C173 quad latch with 3-state outputs and the 74C900 quad bilateral switch. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone(408) 732-5000.

GLASS HIGH VOLTAGE RECTIFIERS EXCEED SPECS. These metallurgically bonded, high voltage rectifiers in a near monolithic glass package give high reliability with low reverse leakage and extreme temperature stability. The 10,000 PIV high-power rectifiers and the 800 PIV fast-recovery rectifiers, typically exhibit less than 50 nA reverse current at PIV. The devices exceed all military and aerospace requirements, including MIL-S-19500. Microsemiconductor Corp., 2830 S. Fairview St., Santa Ana, CA 92704. Phone(714)979-8220. **181**

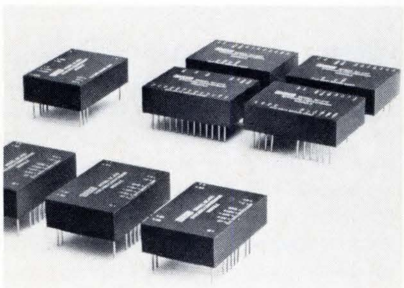
TTL MULTIPLEXERS USE SCHOTTKY TECHNOLOGY. The 8-input digital multiplexer is the logical equivalent of a single-pole, 8-position switch whose position is specified by a 3-bit input address. The 82S30 incorporates an INHIBIT input which, when low, allows the 1 of 8 inputs selected by the address to appear on the f output and, in complement, on the f output. The 82S31 is a variation of the 31 that provides open collector output f for expansion of input terms. The 82S32 is similar except in the effect of the INHIBIT input on the f output. With the INHIBIT input high, both the f and the f output are unconditionally low. Letterhead inquiries only. Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700.

MOS/RAMS RATED AT FULL TEMP. RANGE. This is the first time that designers of military memory systems have such parts available. The 256-bit static memory, called the MM4250, is a pin-for-pin equivalent of the 1101, except that the MM4250 will operate over the −55 to +125°F temp. range. The 1024-bit memory, called the MM4260, is a fully decoded dynamic RAM organized as 1K × 1 bit. It is a pin-for-pin equivalent of the MM5260 (except for the temperature spec), and employs P-channel silicon gates to achieve bipolar compatibility on all I/O lines except the precharge and read/write lines. In quantities of 100, the MM4250 is priced at $28.80, and the MM4260 is priced at $30.80. Letterhead inquiries only. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone(408)732-5000.

SINGLE DIP CONTAINS VIDEO SIGNAL PROCESSOR. The ULN-2125A is a monolithic IC designed for use as a low-cost high quality video processing circuit for black and white as well as color TV receivers. It provides the following signal processing functions: Keyed AGC amplifier to provide forward AGC voltage for video IF amplifiers and tuners equipped with NPN bipolar transistors; composite sync outputs with positive and negative-going signals; reverse AGC voltages for tuners equipped with MOSFETs, PNP bipolar transistors, or tubes in the RF stage; low impedance emitter-follower video output; preset noise detector for gating in the sync separator and AGC detector circuits. The ULN-2125A is available in a 16-lead plastic DIP. Sprague Electric Co., Semiconductor Div., 115 Northeast Cutoff, Worcester, MA 01606. Phone(617) 853-5000. **182**

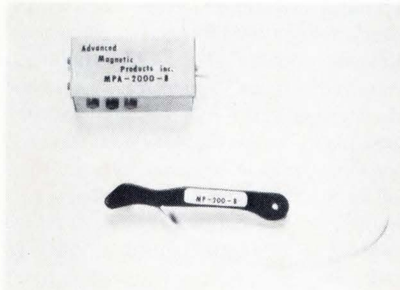


150-MHz 1000-V/μSEC HYBRID AMPLIFIER. When used as an inverting amplifier, the HVA-23 operates at a frequency for unity gain of 100 MHz min. and 150 MHz typical. Frequency for full output is 10 MHz min. and 12 MHz typical. Other features include 1000 V/μsec slew rate, output voltage of +10V, an initial offset voltage adjustable down to zero and voltage gain of 106 dB. Output current is ±30 mA min. and input bias is 150 nA max. It is packaged in a standard 12-pin TO-8 package and meets the requirements of MIL-STD-883. ILC Data Device Corp., 100 Tec St., Hicksville, NY 11801. Phone(516)433-5330. **201**

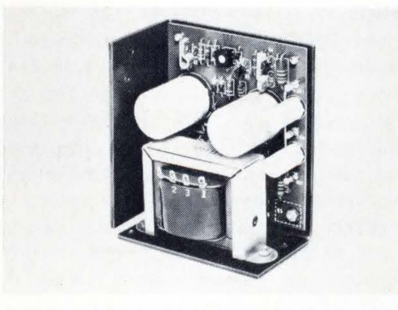


MULTIPLEXED S/D BINARY AND BCD CONVERTERS. A system of miniature plug-in modules can be interconnected to create a multiplexed synchro-to-digital or a resolver-to-digital converter. The new MSDC Series can be utilized in virtually any system requiring interface between multiple synchros or resolvers and a digital computer or visual display. Digital output is in angle format, with resolution to 13 bits binary or 4 decades BCD. A MSDC Series system can accommodate high-level and low-level signals, 60 and 400 Hz carrier frequencies, as well as synchro or resolver signals. Data conversion time is 75 μsec per channel. Binary accuracy is ±3.9 minutes ±1/2 LSB and BCD accuracy is ±0.07° 1/2 LSB. ILC Data Device Corp., 100 Tec St., Hicksville, NY 11801. Phone(516)433-5330. **202**

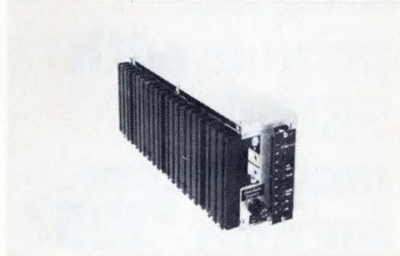
ULTRASTABLE GUNN OSCILLATOR. A new Gunn oscillator features ±1.5 ppm/°C frequency stability without a temperature controller. This rating is equal to several comparable devices on the market requiring a temperature controller to maintain stability. Designated the SSC-11010, this oscillator operates at a fixed center frequency of 6.5 GHz and is mechanically tunable to ±120 MHz. An intergral IC bias regulator is included. The SSC-11010 has a minimum output power of 10 mW. Sperry Electronic Tube Div., Waldo Rd., Gainesville, FL 32601. Phone(904)372-0411. **203**



MAGNETIC PEN AND AMPLIFIER FOR COMPUTERS. The new hard-faced Mag-Pen, Model MP-200-B and the new 2000-gain op amp Model MPA-2000-B are available. The Mag-Pen is designed for computer-oriented point-of-sales, warehouse inventory, display systems, and medical records. It is a hand-operated device that reads pre-recorded magnetically coded data stored on cards, tape, sales slips, etc. The basic construction for the new Mag-Pen is similar to the earlier model, the MP-200-X, however, Model MP-200-B offers longer life with improved resolution. Advanced Magnetic Products, Inc., 7067-1/2 Vineland Ave., N. Hollywood, CA 91605. Phone(213)764-4712. **204**



OP-AMP POWER SUPPLY. The DORPS Series dual-output regulated power supplies are stocked for immediate shipping. They offer current limiting, short-circuit protection and improved regulation. They accept 115/230V, 50 to 60 Hz inputs and are available in two models of 12V at 0.6A and 15V at 0.7A. Construction is open-frame for cost efficiency. All components meet or exceed UL, CSA and computer-grade requirements. Base price is $56.10, with listed dollar-volume discounts to 25% and an additional 5% discount for cash in advance. Techmar Corp., 2232 S. Cotner Ave., Los Angeles, CA 90064. Phone(213)478-0046. **205**

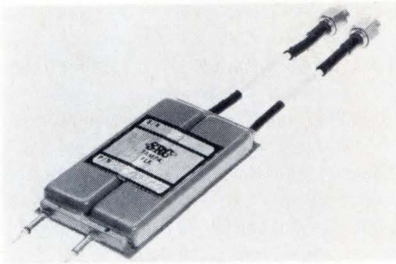


250W MODULAR POWER SUPPLIES. The 662 Series includes the Model 662A05 which delivers 5V at 50A over the operating temperature range of −20°C to +40°C with no moving air required. Efficiency is 70%, and combined line and load regulation is ±0.2%. It accepts either 102 to 130V ac or 198 to 256V ac with no circuitry changes. Output noise and ripple is only 50 mV p-p measured differentially. The 662A05 delivers 250W of power in a 209 in.^{3} package that weighs approximately 10 lbs—2.5W/lb and 1.2W/in.^{3}. Trio Laboratories, Inc., 80 Dupont St., Plainview, NY 11803. Phone(516)681-0400. **206**

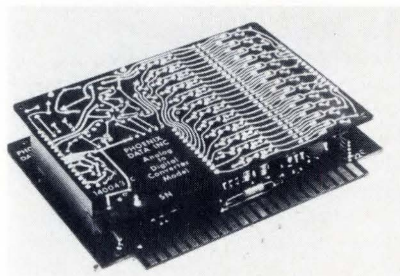
SILICON-TRANSISTOR ELECTRONIC CHOPPERS. Models 40 and 40P are encapsulated units designed to alternately connect and disconnect a load from a signal source. They may also be used as a synchronous demodulator to convert an ac signal to dc. Linear switching or chopping of voltages can be accomplished over a wide dynamic range which extends down to a fraction of a millivolt and up to ±5V. The choppers can be driven from dc to 50 kHz. $19 (100 quantities). Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343. Phone(213)894-2271. **207**

ULTRA HIGH-ACCURACY PRESSURE SENSOR. Type 572 offers the user a rugged transducer with an accuracy of 0.02% which is normally associated with primary standards. This unit is available in ranges from 0 to 1 psi to 0 to 100 psi, gage, differential, or absolute. Hysteresis errors range from ±0.001% to ±0.01% depending upon pressure ranges. Repeatability is better than 0.003%. Sensors are offered with proportional thermostatic controls to insure high accuracy independent of temperature. Datametrics, 127 Coolidge Hill Rd., Watertown, MA 02172. Phone(617)924-8505. **208**

CIRCUITS



GAIN AND PHASE MATCHED 60-MHz HYBRID AMPLIFIERS WITH 60-dB GAIN. Model 8400-1003 has gain matched detectors and video amplifiers. Each amplifier is mounted in its own shielded enclosure and the matched pair is mounted on a common base plate. Center frequency is 60 MHz and the input dynamic range is 40 dB min. The 3 dB bandwidth is ±5 MHz nominal with a bandpass ripple not to exceed +0.5 dB referenced to the center frequency. Small signal gain is 60 dB min. with a noise figure of 3 dB max. measured from a 50Ω noise source. AGC range is 50 dB min. Under $900. Scientific Research Corp., 4722 Eisenhower Blvd., Tampa, FL 33614. Phone(813)884-1411. **209**



HIGH-SPEED A/D CONVERTERS. This series of A/D converters features binary resolution from 8 through 14 bits, with total conversion time as short as 2 μsec. The 800 Series are complete, fully assembled, tested and calibrated plug-in modules incorporating all of the functions necessary to perform conversions, except for power supplies. No external reference voltage source, amplifiers, or trimming potentiometers are required. Conversion times are as follows: 10 μsec for 14 bits, 4 μsec for 12 bits, 3 μsec for 10 bits and 2 μsec for 8 bits. From $295. Phoenix Data Inc., 3384 W. Osborn Rd., Phoenix, AZ 85017. Phone (602)278-8528. **210**

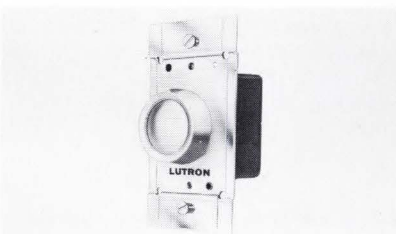
SYNCHRO/RESOLVER STANDARD SIMULATES ROTATING COMPONENT. While testing the slewing characteristics of a system under dynamic conditions, the programmable standard also provides information on repeatability of angular position. Model PSRS-2613 is a source of three-wire synchro or four-wire resolver signals for use in testing S/D converters, resolver-to-digital converters and other rotating components. Programmable functions are: component type; mode (dynamic or static); angular output and rotational velocity. The dynamic mode simulates a rotating component with four possible rotational velocities of 1.5°, 5°, 30° and 200°/sec in either direction. Static angles may be programmed in 0.1° increments over the full 360° with an accuracy of 0.03° with load. The time required to program the PSRS-2613 from one static angle to any other angle is 10 μsec. Singer Instrumentation, 3211 S. LaCienega Blvd., Los Angeles, CA 90016. Phone(213)870-2761. **211**

VOLTAGE CONTROLLED SUBCARRIER OSCILLATOR. Model V-511 has been designed for accurate conversion of varying analog dc voltage to a linearly proportional sinewave frequency. Special consideration has been given to its application within FM-FM telemetering systems. This completely encapsulated plug-in unit embodies an all solid-state design to insure high resistance to shock, vibration, temperature and aging effect. Standard units are available for any of the 64 IRIG proportional or constant-bandwidth subcarrier bands or any frequency range from 300 HZ to 400 kHz. $149. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343. Phone(213)894-2271. **212**

2-DIGIT LED MODULE HAS 0.19-IN. CHARACTERS. The DL-44 is designed for use where multiple digits of 8, 10, 12, 14 or more displays are used and where a multiplex drive scheme has been chosen to minimize electronic costs. Examples of such applications include table-top calculators and point-of-sale equipment. The DL-44 exhibits a high brightness of 250 ftL at a low current of 5 mA per segment. It has good visibility at up to five to six feet of viewing distance. $4.25 per digit. $3.40 per digit for 100 to 999 units. Litronix, 19000 Homestead Rd., Cupertino, CA 95014. Phone(408)257-7910. **213**

MODULAR TRIPLE-OUTPUT POWER SUPPLY. Model Z15AT100TL features outputs of ±15V at 100 mA and 5V at 300 mA with no current derating over the operating range of −25°C to +71°C. Line and load regulation for the 15V outputs are 0.2%. The 5V output is electrically floating, enabling the user to ground either output terminal to obtain a positive or negative 5V. The 5V output also features crowbar overvoltage protection. Input voltage requirement is 115V (±10) ac. Other versions are also available which operate from 100V (±10) ac and 230V (±25) ac. $49. Zeltex, Inc., 1000 Chalomar Rd., Concord, CA 94520. Phone(415)686-6660. **214**

BROADBAND BALANCED MIXER HAS NO BIAS. The 13112NB covers the 1 to 12.4 GHz frequency range in one compact stripline package. It features an i-f frequency of dc to 500 MHz. Using hot-carrier diodes bonded to the stripline board, the 13112NB features low noise (9.5 dB typical) and high isolation. Balanced mixers which operate in octave bands from 0.5 to 18 GHz are available. Microwave/Systems, Inc., 1 Adler Dr., Syracuse, NY 13057. Phone(315)437-9951. **215**



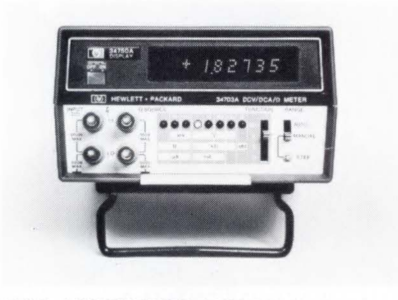
FAN SPEED CONTROLS REDUCE FAN AND BLOWER NOISE. The Fandial solid-state fan speed controls continuously vary fan and blower speeds from full to any required lower speed. Used with shaded-pole, permanent split-capacitor and universal (ac-dc) motors, Fandial effectively reduces fan and blower noise. Controls allow any lower speed for proper air movement to remove smoke and odors without creating cooling discomfort. The controls turn on at full speed then rotate clockwise to low speed. Lutron Electronics, Co., Inc., Coopersburg, PA 18036. Phone(215)282-3800. **216**

UNIVERSAL BRIDGE FOR R-C-L MEASUREMENTS. Using an ac bridge technique, Model 4265A measures L, C and R at 1 kHz to an accuracy of 0.2% of reading. Dissipation factor (D) and quality factor (Q) are also measured. Inductance is measured from 0.1 μH to 1111 H and capacitance is measured from 0.1 pF to 1111 μF, both in seven ranges. Seven resistance ranges cover from 0.1 mΩ to 1.111 MΩ. Q, measured at 1 kHz for series L or parallel C, is from 1 to 10. D, for parallel L or series C, is from 0.001 to 1. Both are measured to an accuracy of 5%. $540. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. Phone(415)493-1501. **183**

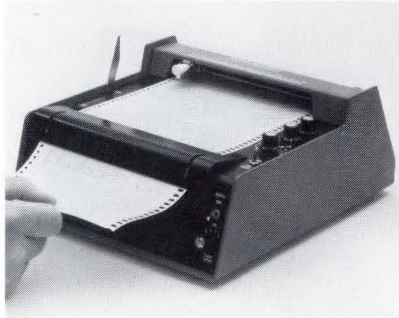
E.S.R. METER/DIGITAL OHMMETER. Model 273 reads the "equivalent series resistance" of capacitors or resistors at 100 kHz. The instrument can resolve down to 1 mΩ for capacitors greater than 0.5 μF. Two other ranges allow higher resistance measurements on smaller capacitors. The Model 273 is self-balancing and operates on a "four wire" principal. Its 2-1/2-digit decimal display has BCD output. The meter may also be used as a digital ohmmeter to read resistances (at 100 kHz) between 1 mΩ and 20Ω. $735. Clarke-Hess Communication Research Corp., 43 W. 16th St., New York, NY 10011. Phone(212)255-2940. **184**

SWEEP-FREQUENCY IMPEDANCE MEASUREMENTS TO 500 MHz. The capability to make 400-kHz-to-500-MHz sweep-frequency measurements of impedances from 0.5Ω to 1 MΩ and of admittances from 1 μmho to 2 mho is now possible with a new $595 accessory to the Model 1710 rf network analyzer. The 1710-P5 immittance probe provides the measurements as rectilinear displays of the magnitude and phase of the impedance or admittance vs frequency, or as a polar display of the real and imaginary components. Bias can be applied at the rf input for tests of semiconductor devices and the probe is supplied with all necessary accessories. General Radio, 300 Baker Ave., Concord, MA 01742. Phone(617)369-4400. **185**

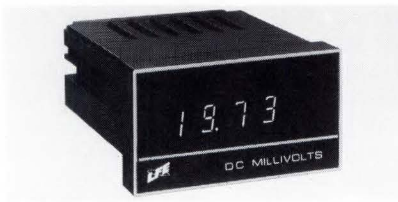
INDUSTRIAL DPM. Series 3000B general-purpose DPM features a 3-1/2-digit, 0.3-in.-high LED display (0.8 in. optional), an aluminum case and a new and improved dual-slope A/D converter. The display is updated at a rate of 5 times/sec. In the external control mode, the display is updated with each conversion. The conversion rate can be adjusted up to 100/sec. $198. Electronic Research Co., 7618 Wedd Ave., Overland Park, KS 66204. Phone(913)631-6700. **186**



TWO MULTIMETER MODULES. A 5-1/2-digit display and a high-sensitivity multifunction unit are added to Hewlett-Packard's low-cost 3470 snap-on system. The $550 3470A display module will lock on to any center section or voltmeter module to make a complete DVM. In combination with the Model 34701A dc voltmeter plug-on, the unit forms a 5-1/2-digit DVM capable of measurements from 1 to 1000V, with an accuracy of 0.025% of reading, and at a total cost of only $700. Model 34703A dc/dcA/ohmmeter module is another $550 snap-on that can be used with either the Model 34740A 4-1/2-digit display or the new 34750A 5-1/2-digit display. The basic sensitivity of the Model 34703A is 1 μV on dc voltage. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. Phone(415)493-1501. **187**



HIGH-PRECISION 5-IN. STRIP-CHART RECORDER. Model 726 markets for $495, weighs 7 lbs, has a front-mounted fingertip control panel and an automatic clutch for advancing or rewinding manually without adjustments. Offering spans from 1 mV to 100V full scale with a constant 10-MΩ input resistance, Model 726 also features 12 chart speeds, a 30 in./sec pen response and an accuracy of 0.5% of full scale. Disposable felt pens are standard and can be ordered with a remote pen lifter. All models are guaranteed for 1 year. Precision Standards Corp., 1701 Reynolds, Santa Ana, CA 92705. Phone(800)854-3253, toll free. **188**



3-1/2-DIGIT DPM WITH 10-μV RESOLUTION. Model 4352 is available off-the-shelf in a 20-mV range with 10-μV resolution. The full scale sensitivity of 19.99 mV provides a low-cost digital readout. A planar 7-segment green display is easy to read. Options include BCD output, read-hold and programmable decimal points. $195 (20-mV range). LFE Corp., 1601 Trapelo Rd., Waltham, MA 02154. Phone(617)890-2000. **189**

OSCILLOSTORE FOR FAULT RECORDING. The system continuously stores and then accurately reproduces traces for important measured variables after a delay of roughly 300 msec. The UV recorder is triggered before the termination of the delay and can thus provide a precise picture of the start of the fault as well. The frequency range for the electronic delay module is roughly 1 kHz for 6 measuring channels and fully suffices for the majority of fault analyses. The operating state before, during and after the fault can be continuously recorded by one single recording unit with a uniform resolution. Siemens Corp., 186 Wood Ave. South, Iselin, NJ 08830. Phone(201)494-1000. **190**

TIME-INTERVAL GENERATORS. Series 600 has been conveniently packaged in 1-, 2-, 3- and 4-channel models. Total capacity can be expanded by operating any number of instruments in serial or parallel, utilizing a common time-base clock. Available are Model 601 (1 timing channel) at $1700; Model 602 (2 timing channels) at $2500; Model 603 (3 timing channels) at $3250, and Model 604 (4 timing channels) at $3950. Systron-Donner Corp., Datapulse Div., 10150 W. Jefferson Blvd., Culver City, CA 90230. Phone(213)836-6100. **191**

PORTABLE PANORAMIC RECEIVER. The YIG tuned PM7800 can display the entire frequency spectrum from 1 to 18 GHz or any selected portion of it in a single sweep with 20-MHz resolution. The display may be either logarithmic or linear, at the option of the operator. Built-in sweep circuits permit displays on six calibrated time axes from 50 MHz/div. to 2 GHz/div. An external sweep may also be used, or the sweep function may be disabled and the receiver manually tuned. Accuracy is ±0.25% +25 MHz and resolution is 20 MHz. Test & Measuring Instruments, Inc., 224 Duffy Ave., Hicksville, NY 11802. Phone(516)433-8800. **197**

PULSE RECORDER DESIGNED FOR 42 CHANNELS. Oscilloreg MO2001 ac-dc recorder has a maximum of 42 measurement channels, including one time-marking channel and covers a frequency range of 0.12 to 120 Hz. The recorder has eight paper-feed rates from 50 mm/sec to 1 m/sec with up to 1-msec resolution. A paper footage counter is included. The recorder can be used as a portable unit or it can be rack mounted. It can be used to measure relay pick-up and drop-off times, contact bounce and irregular switching sequences with relays, contactors and contact drums. Siemens Corp., 186 Wood Ave. South, Iselin, N J 08830. Phone(201)494-1000. **192**

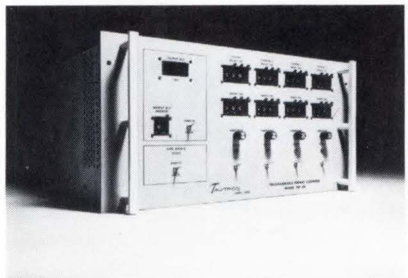
PORTABLE PROFILE MEASURING SYSTEM. Model 15 consists of a 32 lb drive, a ruggedized universal probe and a compact 14 lb controller with an integral recorder. The system sells for $5500. The controller has a complete electronic carrier system which provides sensitivity selection of nine magnification ranges from 50 to 20,000 times. The controller's built-in recorder has a 2-in. (50-mm) single-channel chart and three chart speeds—0.1, 0.2 and 2 in./sec. Either English or Metric charts can be easily inserted on location. Gould, Inc., 4601 Arden Dr., El Monte, CA 91731. Phone(312)693-2550. **193**

ELECTRONIC GALVANOMETER AND ΔVM OPTIONS are available as a factory installed option for EDC's standard line of dc voltage and current calibrators and reference standards to provide high-accuracy measurements and voltages as low as 1 μV. The input impedance is 10 MΩ when used differentially and infinite when used as a galvanometer. Sensitivity is 1 μV and accuracy is ±0.005% of setting. $225. Electronic Development Corp., 11 Hamlin St., Boston, MA 02127. Phone(617)268-9696. **194**

ENDLESS-LOOP INSTRUMENTATION RECORDER. The low-cost ($3480) recorder developed by N. V. Philips of Holland provides up to 90 days of unattended operation. Three standard versions of the Memoloop are available: 6-channel instruments operating at either 3/4 in./sec; or at 2-1/4 in./sec; and a 13-channel instrument operating at 2-1/4 in./sec. Frequency response at 3/4 in./sec is 0 to 70 Hz (−3 dB); at 2-1/4 in./sec it is 0 to 1000 Hz (−3 dB). Input impedance is 10,000Ω. Test & Measuring Instruments, Inc., 224 Duffy Ave., Hicksville, NY 11802. Phone(516)433-8800. **195**

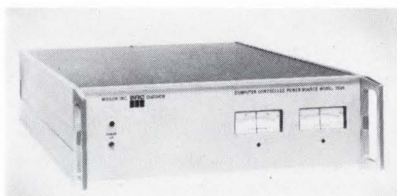
POWER SUPPLY EXTENDS LASER'S RANGE. The K-25 power supply is a 5-kW, 10-kV unit for use with Korad's ruby and glass laser systems. In use, it increases the versatility of the lasers by boosting the average laser output power and by improvements in pumping efficiency of the laser system. New features include a positive-switching circuit to prevent accidental prefiring of the flashlamp. $8950. Korad Dept., Union Carbide Corp., 2520 Colorado Ave., Santa Monica, CA 90406. Phone(213)829-3377. **196**

EQUIPMENT



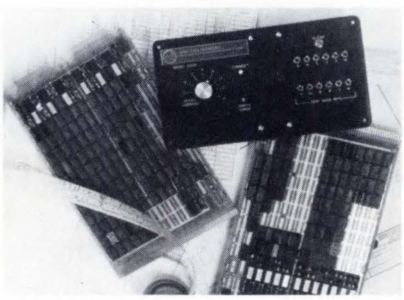
PROGRAMMABLE TIMING UNIT AND PULSE DRIVER. The PFC-101 allows precision control of width and delay out to 999 nsec. It has 4 independent channels. Resolution of both width and delay settings on each channel is a constant 1 nsec, irrespective of the programmed value of width and delay. The unit operates to 35 MHz and accepts asynchronous channel-to-channel inputs. Width plus delay duty cycle approaches 200%. The unit can be programmed by the front panel by remote TTL signals, or both. $7995 (4 channels). Tau-Tron, Inc., 685 Lawrence St., Lowell, MA 01852. Phone(617)458-6871. **198**

VHF SWEEP GENERATOR. Model SMG-12 is designed to be used in conjunction with the Lectrotech SMG-39 or other equivalent generator. The combination of the two instruments permits one to check alignment on each of the vhf TV channels. Also supplied as part of the alignment package is the Model SMG/uhf balanced detector. This device permits alignment checks on each of the uhf channels 14 through 83. The SMG-12 is supplied with all necessary cables and probes. With SMG/uhf and cables it is priced at $249.50. Lectrotech, Inc., 5810 N. Western Ave., Chicago, IL 60659. Phone(312)769-6262. **199**



COMPUTER-COMPATIBLE dc POWER SUPPLIES. Two computer controlled dc power sources feature digital-programming control and a wide range of computer-compatible interface modules. Designated Models 3536 and 3537, the compact rack or bench mounted units permit 16-binary-bit or 17-BCD-bit programming. Interface or isolation circuits can be selected and easily changed in the field. Ac input to dc output isolation is 10,000 MΩ and 10 pF. Output resolutions as fine as 500 μV are available. In addition, any range of full scale and step voltages are also available, including non linear step functions. $1495. Moxon, Inc./SRC Div., 2222 Michelson Dr., Irvine, CA 92664. Phone(714)833-2000. **200**

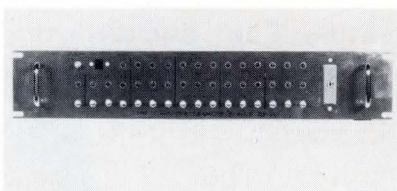
FAST-MAKE/FAST-BREAK KEYSWITCH DESIGNED FOR COMPUTERS, controllers, business machines and scientific calculators. The Type S signal keyswitches provide manual entry of commands into systems employing DTL, TTL or MOS circuit logic. They are available only as mounted arrays on a common pc board for low cost and perfect columnar alignment. The keyswitches use the reliable "pancake" design that employs a simple, dome shaped snap disc which when pressed, makes electrical contact with a gold plated conductor. 21¢ to 29¢ per-key mounted on the customer's board. Mohawk Data Sciences Corp., Colorado Instruments Div., 1 Park St., Broomfield, CO 80020. Phone(315)792-2202. **245**



INTERFACE INCREASES DATA TRANSFER RATE. The Model 2300 allows a 5-fold increase in data transfer rate between Control Data Corp. computers and Varian 620 minicomputers. Available with the Varian priority memory access (PMA) feature, it permits the 620 to serve as a front end for the larger CDC equipment in applications such as data acquisition, telecommunications, graphics with interactive control, or other special control I/O functions. Use of the minicomputer permits farm out of production-slowing operations. The larger computer is relieved of housekeeping chores and may devote most of its time to pure 'number crunching.' Sierra Data Systems, Inc., 168 E. Del Mar Blvd., Pasadena, CA 91105. Phone(213)792-2131. **246**

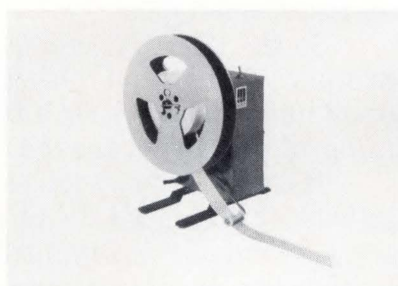
LOW-COST PRINTER HAS ONLY 2 MAJOR MOVING PARTS. The Series 200 printer is said to be the only non-impact electroresistive printer available in the 200 cps range. Due to its ultimate in modularity, this is the first piece of electronic equipment of this complexity said to be capable for self-service by any end user. The SCOPE Series 200 is thought to be the only serial character printer (thus allowing direct keyboard entry) in this advanced speed range. It will O.E.M. for less than $1350 in small quantities with shipments beginning in June. End user pricing is available from the manufacturer. Scope Data, Inc., 5870 S. Tampa, Orlando, FL (32802). Phone(305)859-1410. **247**

300M-BIT DISC SYSTEMS OFFER LOW COST. The field expandable 3320 disc systems are available in four models; 75M, 150M, 225M and 300M-bit configurations. These systems feature a track density of 164 tracks per in., average head positioning time of 30 msec and data throughput rates of up to 6.45Mbps. They have the ability of expanding up to eight units. Data integrity is assured by using non-contact heads which automatically retract in the event of a power failure. Remex, 1733 Alton St., Santa Ana, CA 92705. Phone(714)557-6860. **248**

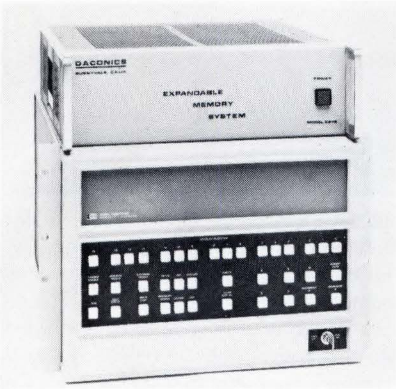


MICROPROGRAMMED BRANCH DRIVER AVAILABLE FOR PDP-11. The MBD-11 is a 16-bit microprocessor CAMAC branch driver (BD). The unit can function as a standalone controller for data logging and control applications and as an 8 DMA channel multiplexer/branch driver. The MBD-11 used with the PDP-11 serves as a pre-processor, parallel processor and as a high-speed CAMAC BD. The MBD-11 has a 16-bit read-write bipolar memory that is expandable to 1024 words in 256-word increments. The unit has 16 microinstructions that can select any memory source and transfer to any register and perform one of 16 control functions in 350 nsec. The unit can initiate 25 unique interrupts to the PDP-11. Diagnostics and a macro-assembler are furnished with the MBD-11. Also offered is a simulator for testing PDP-11 interfaces and a Nova branch driver. BiRa Systems, Inc., 9611 Acoma S.E., Albuquerque, NM 87123. **249**

COMM TERMINAL FEATURES DUAL CASSETTES. The Model 4200 is intended for high-speed data communications and data storage applications. It features full remote control with each deck independently controllable, switch selectable speeds to 2400 Baud, high-speed search and data editing. It has dual interfaces for terminal and modem operation. The unit is switch selectable for on-line or off-line operation. Independent read/write speeds are featured and the 4200 is programmable. It is plug compatible to most data entry terminals such as Teletype, Hazeltine 2000, TI 700 series printers, Univac DCT 500, TermiNet 300 and many others. Techtran Industries, Inc., 580 Jefferson Rd., Rochester, NY 14623. Phone(716)271-7953. **250**



PAPER-TAPE WINDER FOLLOWS RAPID STARTS AND STOPS. The TM/270 collects tape that is being expelled from readers or punches at rates up to 115 cps or 11-1/2 ips. The unique tape tensioning control arm and servo braking system allows the device to collect tape even when the tape source is starting and stopping quickly. The winder is supplied with an 8-1/2-in. diameter, separable tape reel. Take up reel capacity is approximately 800 ft. $90. Data Specialties, Inc., 1548 Old Skokie Rd., Highland Park, IL 60035. Phone(312)831-3750. **251**

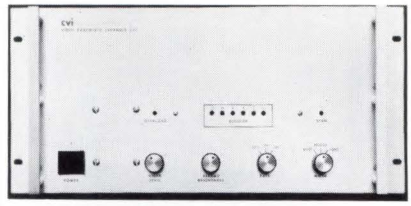


ADD-ON MEMORY FOR H-P USERS REQUIRES NO CPU CHANGES. HP 2100-series computers can now be expanded up to 32k core with the 2970 core memory subsystem. A direct add-on, the memory requires no hardware changes to the CPU and works with the existing installed core. A self contained power supply conserves CPU power for peripheral I/O controllers. All existing software, including memory diagnostics, run as they are. Memory data access time is 250 nsec. Daconics, 925 Thompson Pl., Sunnyvale, CA 94806. Phone(408)732-2634. **253**

PLUG-IN UNIT INTERFACES TELETYPE WITH INTEL COMPUTERS. The SIM 4-01 and 4-02 can be interfaced simply and economically to a standard Teletype machine with this solid-state plug-in reader control package. It is housed in its own plug-in case and requires little effort to install. Complete instruction sheet for installation is included. The new reader control is MOS or TTL compatible with simple circuit modification. SenSitrol, Inc., 200 S. 4th St., P.O. Box 150, Albion, IL 62806. Phone(618)445-2323. **254**

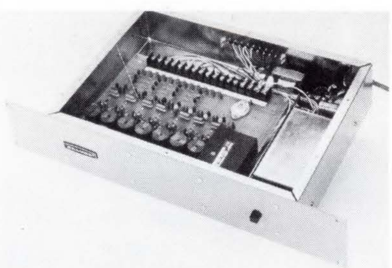
PCM BIT SYNCHRONIZER OFFERS BIT RATES FROM 1 kBPS TO 2 MBPS. The Model 7130 is thumbwheel programmable and has independent input and output selection in all standard IRIG codes. It accepts perturbed data in any of the 8 IRIG codes via one of 4 selectable input channels. It outputs an in-phase clock, regenerated (cleaned) input data, NRZ-L data and any selected IRIG codes. The clock is generated by a phase locked loop with wide or narrow tracking. Under $4500. Coded Communications Corp., 1620 Linda Vista Dr., San Marcos, CA 92069. Phone(714)744-3710. **255**

COMPUTER PRODUCTS

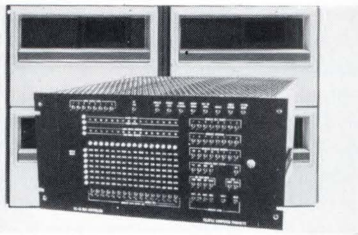


VIDEO EXPANDER INTERFACES COMPUTERS AND TV for graphic data display. The Model 261 may also be used for video communications terminals. Any properly formatted analog or digital input may be fed into the unit at a slow rate and used to build a continuously refreshed image on a TV screen. A 12-in. magnetic disc memory is used for image storage. $5500. Colorado Video, Inc., P.O. Box 928, Boulder, CO 80302. Phone(303)444-3972. **256**

DIGITAL-CLOCK KIT OFFERS LED DISPLAY. These clocks display 4 or 6 digits. The units operate on either a 12- or a 24-hr cycle and a one pulse per sec colon may be utilized in the 4-digit clock. The kits feature plated-through circuit boards and LSI circuitry with low-profile mounting sockets and BCD outputs. They have an internal digit multiplex oscillator and individual timeset buttons. Included with the kit is an illustrated assembly manual with sections on theory of operation, trouble shooting and step-by-step assembly procedure with schematics. MITS, Inc., 5404 Coal Ave. S.E., Albuquerque, NM 87108. Phone(505)265-7553. **257**

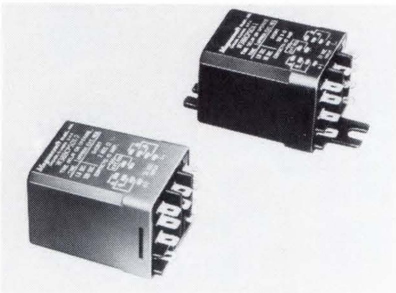


CONVERT TOUCH-TONE SIGNALS TO DIAL-PULSE SIGNALS. The TT-DP1 converter can be used in radio or telephone systems. For high-speed signalling, the TT-DP1 has a built-in cyclic memory. This lets you enter up to 18 touch-tone digits in rapid succession without congestion. Immediate cancellation of the signal conversion is possible if there is a mistaken touch-tone entry. TT-DP1 converters are available on 19-in. rack panels or in NEMA-3 housings. Both models are supplied in either 24V dc, 48V dc or 117V ac versions. $845 to $870. Bramco Controls, Div. of Ledex Inc., College and South Sts., Piqua, OH 45356. Phone(513)773-8271. **258**

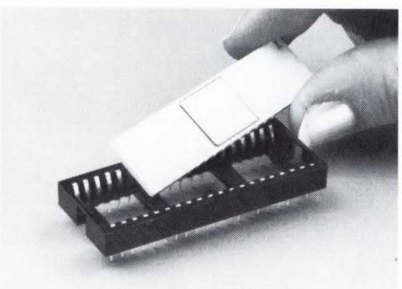


HIGH-STORAGE CAPACITY DISC SYSTEM STORES 116M BYTES. Complete disc systems for Interdata Computer Models 3, 4, 5, 50, 70, 74, and 80 and GE PAC Model 3010/2 computers, provide dual density storage of up to 116 million 8-bit bytes per single disc storage cabinet on IBM 2316 type moving head-disc units. Systems consist of a DC-16-1 disc controller and up to 8 Telefile Model DD-215 dual density disc drives. Many disc controller functions normally performed by software are automatically accomplished by hardware. Track-to-track access time is 10 msec, and max. access time is 55 msec. Data transfer rate is 312,000 bytes per sec. DC-16-1—$8200. Disc drives—$22,000. Telefile Computer Products, Inc., 17795, Sky Park Circle, Irvine, CA 92664. Phone(714)557-6660.
259

PRINTING CALCULATORS HAVE STORED PROGRAMS. The C 6200 series programs are applicable to general business problems such as calculation of selling price from cost and desired gross profit margin, automatic scheduling of compound interest calculations, preparation of depreciation schedules, automatic extensions with proof totals, proration of amounts, distribution by percentages, area/volume calculations, job or process costing, determination of amount and percentage of increase or decrease for comparable periods as well as logarithm and standard deviation programs for financial analysis and business forecasting. The programs are stored permanently in ROM consisting of LSI circuit chips. Business Machines Group, Burroughs Corp., Detroit,
260

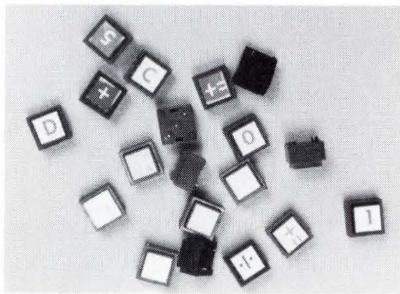


TIME DELAY RELAY IS A HYBRID. In a package no larger than a 388 general purpose relay, this class 388 is a composite of solid-state timing, isolated from a high-quality general-purpose relay. When control voltage is applied to the input terminals, the solid-state time delay is initiated. The controlled period of time is repeatable to ±3% accuracy. When the timing network reaches its predetermined duration it energizes the general-purpose relay to switch up to 10A at 115V ac or 28V dc on DPDT contacts. Transient protection to twice input voltage for 8 msec is included. $14.80 to $18.50. Magnecraft Electric Co., 5575 N. Lynch Ave., Chicago, Il 60630. Phone(312)282-5500. **261**



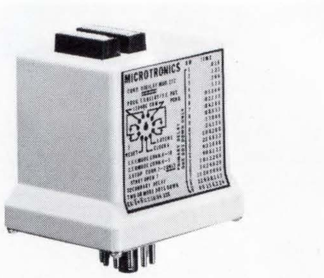
LOW-PROFILE RECEPTACLE DESIGNED FOR LEADLESS SUBSTRATES. Increased semiconductor chip sizes have forced the introduction of ceramic packages with larger well sizes and metallized edges. Side metallization not only increases space available for active chips but eliminates the package leads and their inherent drawbacks while maintaining pluggability when used with receptacles. Extending only 0.225 in. above the pc board, this low-profile receptacle from AMP Inc., is designed to accommodate the new side metallized leadless ceramic packages. Accepting 0.080-in. thick ceramic packages up to 2.020-in. long and 0.578 (−0.013 + 0.032 in.) wide the receptacle is only slightly larger than the ceramic package itself. AMP Inc., Harrisburg, PA 17105. Phone(717)564-0101. **262**

GaP LEDS OFFERS HIGH EFFICIENCY AND BRIGHTNESS. Compared to gallium-arsenide phosphide, these gallium-phosphide LEDs offer superior brightness at lower current levels. The XC-200 is a low-profile point source of light available with both clear and red epoxy lenses. The high-profile version, the XC-300, has a magnifying lens available in both clear and red. Typical specifications are 3 millicandella for the XC-300 series and 0.5 millicandella for the XC-200 series at operating currents as low as 10 mA. Pricing is $1.25 for 1-99, $.87 for 100-999 and $.76 for 1000-up. Xciton Corp., Shaker Park, 5 Hemlock St., Latham, NY 12110. Phone (518)783-7226. **263**

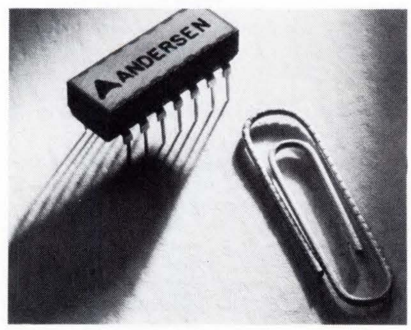


MINIATURE SWITCH HAS TACTILE FEEDBACK. The LM miniature gold v-bar switch is a SPST-N.O. unit. Switching contact is achieved by moving a gold-wire beam spring into the vee formed by the conical points of the 2 gold plated contact rods. The spring-on-spring design has the high hysteresis desired in modern keyboard switching. The solder mounted units are designed for use in hand-held devices. They can be mounted on 1/2-in. centers. The complete keyboard including pc board extends 1/4 in. below the enclosure panel surface and has 0.70 in. of plunger travel to give a sense of movement. 16¢ each in quantities of 50,000 per month. Mechanical Enterprises Inc., 5249 Duke St., Alexandria, VA 22304. Phone(703)751-3030. **264**

3-DIGIT LED DISPLAY AIMED AT CALCULATOR MARKET Each digit in the NSN-33 is 1/8-in. high and consists of 7-segments and a right-hand decimal point. Segment and decimal point anodes of the 3-digits are internally connected in parallel making multiplex operation easy. The digits are spaced on 0.2-in. centers for easy end-to-end stacking of 6, 9, or 12 or more digits. The NSN-33 comes in a 12-pin DIP. A low-current drive of only 1 mA average per segment provides adequate brightness in typical applications. Maximum average current per segment is 8 mA and the maximum reverse voltage rating is 5V. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone(408)732-5000.

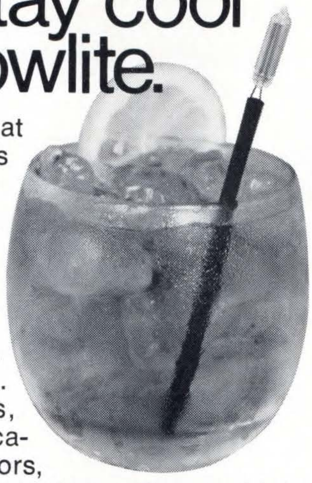


TIME DELAY RELAY CAN BE SET FROM 16 MSEC TO 9 HRS. The M-272 "DIGILAY" digitally controlled time delay relay/flip-flop/pulser has an accuracy and repeatability of better than 0.05% of full range. It is housed in a standard time delay relay housing terminating in a 11-pin pluggable connector. The DPDT relay is rated at 10A/120V ac and is sealed twice for industrial environments. The desired delay is generated by depressing one or more switches located on top of the unit. These switches are normally covered with a transparent cover to protect them from accidental setting and dust. Start, stop and mode of operation is controlled by contact closure. $69. Microtronics Corp., 203 Gateway Rd., Bensenville, IL 60106. Phone(312)595-8330. **266**



DIP DELAY LINE DESIGNED FOR COMPUTERS. The units range in delay from 10 to 200 nsec long. Taps are located at increments of 10% of total delay. Tolerances on delay are ±5% or 1 nsec, whichever is greater. Attenuation is less than 0.5 dB. They operate over a −55°C to +85° temperature range, with a temperature coefficient of delay of 70 ppm/°C maximum and meet MIL environmental specifications. Features include: large delay/rise time ratio, 4 standard impedances, 5 standard delays and thermal stability. Anderson Labs, 1280 Blue Hills Ave., Bloomfield, CT 06002. Phone(203)242-0761. **267**

Competition is hot...stay cool with Glowlite.



Glowlite takes the heat off manufacturers who require special design neon lamps. Whether used as indicators in electrical appliances . . . or industrial and commercial equipment... Or as Inner-Vators . . . as arc suppressors, flashers, fuse indicators, humidity sensors, oscillators, power line testers, relays and lots of other things . . . Glowlite neon lamps give you the benefits of low cost, long life and reliability. Stay cool. Write for our catalog.

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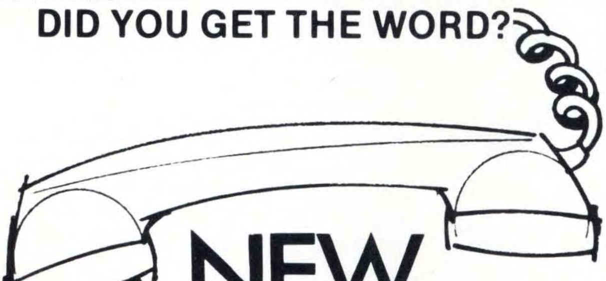

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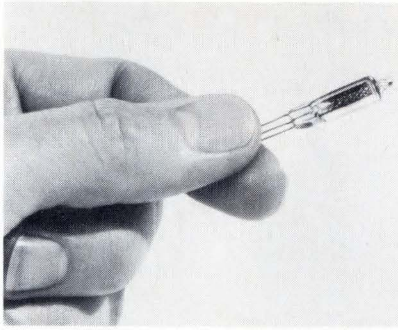
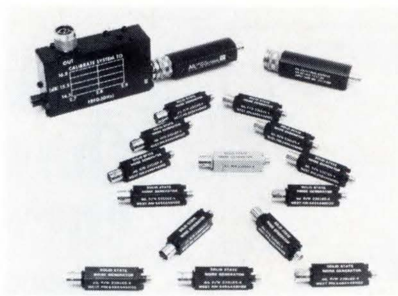
COMPONENTS/MATERIALS

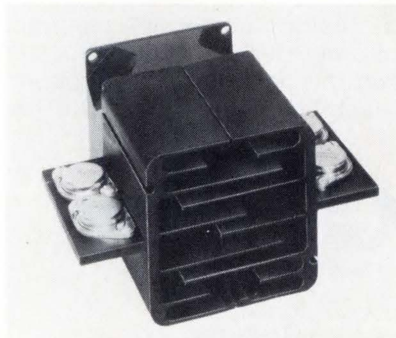


SUBMINIATURE-SWITCH TUBE TRIGGERS BY BODY IMPEDANCE. The ZA1006 for TV touch-control tuning and channel indication is a neon filled diode whose large and stable difference between ignition and maintaining voltages permits a highly reliable response when triggered. Ignition potential for the ZA1006 is 172V and its maintaining potential is only 107V. It draws only 3 mA of cathode current when switched on. Ignition delay is as low as 20 msec, depending on circuit configurations. Since the ZA1006 is a neon filled diode, it produces a bright orange light when switched on. Amperex Electronic Corp., Hicksville Div., Hicksville, NY 11802. Phone(516)931-6200. **268**



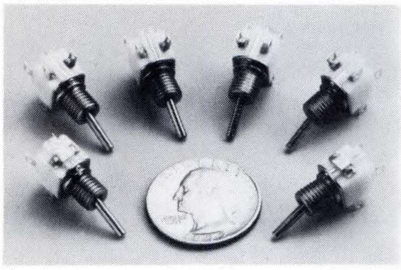
SOLID-STATE NOISE SOURCES OPERATE UP TO 18 GHZ. With typically a 15% bandwidth, these devices can be provided with excess noise ratios of as much as 42 dB. Low-power, small-size and high-level output make them ideal for system noise monitoring applications. A high-excess noise ratio permits the user to inject noise into a receiver system through a 20- or 30-dB coupler and still attain a reasonably high, injected noise power in the system for measurement of operating noise temperature or noise figure. Small size and the need for only a single coaxial power connection make antenna feed mounting particularly convenient. AILTECH, Farmingdale, Long Island, NY 11735. Phone(516)595-5823. **269**

STEPPING MOTORS FEATURE HIGH TORQUE-TO-SIZE RATIOS. The size 34 permanent magnet stepping motor is designed for 1.8°, 1.875° and 5° steps, torque ratings from 100 to 450 oz-in., and slew rates to 20,000 pps and up. The size 23 unit has 1.8°, and 5° steps, 25 to 100 oz-in. torque ratings and slew rates to 10,000 pps. In the variable reluctance types, sizes 8 thru 23 steppers are available with 3 or 4 phase windings and a wide range of step angles, voltages and torque ratings. The P.M. units are also used as ac synchronous motors with shaft speed equal to 1.2 times the applied frequency. Eastern Air Devices, Inc., Dover, N H 03820. Phone(603)742-3330. **270**



FORCED AIR HEAT SINKS DECREASE SIZE AND COST. A 20 to 40% decrease in cost and a 50% reduction in size and weight over comparably performing units are features of these natural or forced air convection heat sinks. These extruded heat sinks consist of 2 identical halves with tongue-and-groove configurations. A standard 3-1/8-in. fan fastens directly to the unit. These extrusions may be ordered in any length and cut as required. A number of individual units, in modular form, can be assembled using threaded rods. Tor Heat Sink Div., Precision Dipbraze Tor, Inc., 14715 Arminta St., Van Nuys, CA 91402. Phone(213) 786-6524. **271**

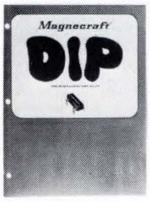
EVALUATION KITS OF SOLID-STATE SWITCHES. All 4 kits contain a pc board for switch mounting, a detailed set of design and application notes and four Series 200 solid-state switches. Evaluation Kit F1 contains 4 momentary-type switches which require a power supply that is floating with respect to earth ground. Kit F2 contains 3 momentary and 1 latching-type switch for floating operation. Evaluation kit G1 is supplied with 4 momentary-type switches that require a grounded power supply and kit G2 contains 3 momentary and 1 latching-type switch for use with grounded power source. $25.00. Magic Dot, Inc., 40 Washington Ave. S., Minneapolis, MN 55401. Phone(612)333-8161. **272**



SUB-MINIATURE TOGGLE SWITCH OPERATES FROM dc TO OVER 1 GHz. The Giga-Switch provides reliable operation over a wide-frequency range. This switch exhibits low-internal resistance, low inductance and low capacitance since it was designed specifically for low-energy, high-frequency applications. Life is 100,000 cycles. There are 2 models presently being offered—a standard DPDT and a modified DPDT with a shorting strap across 2 terminals as typically used in attenuators. Quantity 1-9—$5.50 Large quantity—$3.00. Elemetrics Corp., 12 Maple Ave., Pine Brook, N J 07058. Phone(201)227-2000. **273**

INFRARED ARRAYS DRIVE LOGIC CIRCUIT ICs. This family of 9-, 10-, and 12-position matched-pair IR source and sensor arrays is designed for all types of optoelectronic recognition equipment. The units can be used to sense reflected light as well as incident light through punched holes. Each array pair consists of a modular array of gallium-arsenide infrared emitting diodes and a matching array of infrared phototransistor sensors. Standard digital integrated circuits may be operated from the $5V_{CE}$ at 50 mA sensor output without amplification. Compatible interfacing with DTL, RTL, or TTL circuits and information transfer from laser sources is possible. Sensor Technology, Inc., 21012 Lassen St., Chatsworth, CA 91311. Phone(213)882-4100. **274**

Pc CONNECTOR ELIMINATES CIRCUIT BOARD MISMATING. Featuring the ability to be keyed to 36-polarization positions, the 50-pin EG-Series connectors are made of a new highly resilient polyester thermoplastic, which operates at up to 150°C; a heat capability previously attainable only in more brittle plastics. The connectors are available in a right-angle board mounted plug with chassis mounted receptacle for wire-wrap terminations and an environmentally sealed plug and receptacle with crimp-removable contacts. $.15 per mated circuit. Hughes Connecting Devices, 500 Superior Ave., Newport Beach, CA 92663. Phone(213)670-1515. **275**

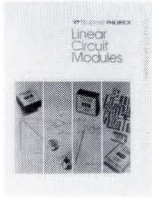


DIP REED RELAYS. This 12-pg. catalog describes the most complete line of DIP reed relays offered by any relay manufacturer. These relays, 22 types in all, are offered with 5, 6, 12 and 24V dc coils. Included are contacts of 1 form A, 2 form A, 1 form B, 1 form C and 2 form C in both 8- and 14-pin configurations. The most noteworthy of these DIPS being the position free mercury wetted types. Magnecraft Electric Co., 5575 N. Lynch Ave., Chicago, IL 60630. **217**

SEMICONDUCTOR DATA LIBRARY. In this 3-volume set, books 1 and 2 provide complete data sheet specifications of all Motorola manufactured discrete semiconductors. The reference volume contains a technical description of all EIA registered semiconductors made by the industry (regardless of manufacturer), as well as a set of selector guides covering all discrete families made by Motorola. Price is $6.50 for the basic set, $10 for the set and updatings. Motorola Semiconductor Products Inc., 5005 E. McDowell Rd., Phoenix, AZ 85008. **218**

PCM ENCODERS. Programmable pulse-code-modulator (PCM) encoders recently introduced as standard products are described in a 6-pg. illustrated folder that lists general information, system specifications and detailed descriptions. The encoders described offer customer programmable format storage through readily available electrically programmable read-only memories (EPROMS). Spacetac, Inc., Burlington Rd., Bedford, MA 01730. **219**

SEMICONDUCTORS. This 44-pg. catalog lists detailed specifications on more than 6000 semiconductor devices. Included in the catalog are temperature compensated reference diodes, zener diodes, high-speed, high-power switching transistors and silicon transient voltage suppressors. It has complete JEDEC cross-reference index listings on JEDEC zener diodes. General Semiconductor Industries, Inc., P.O. Box 3078, Tempe, AZ 85281. **222**



LINEAR SHORT FORM CATALOG features the 1421 series of economy FET microcircuit op amps. Also described is the Model 1324 fast-settling monolithic op amp which offers guaranteed specifications to accurately resolve high-speed data. A section on nonlinear function modules and low-cost modular power supplies is included. Teledyne Philbrick, Allied Dr. at Route 128, Dedham, MA 02026. **223**

STANDARD CORDIP NETWORKS. Four standard CORDIP resistor networks available off-the-shelf are described in a 2-pg. illustrated data sheet (EPD-2). The standard functions are 14- and 16-pin pull-up packages and 14- and 16-pin in-out packages. Resistance values are listed and electrical and environmental performance data is given. CORDIP network combinations are available in customized designs using combinations of up to 23 resistors, capacitors and diodes in 16-pin packages. Electronic Products Div. of Corning Glass Works, Corning, NY 14830. **224**

ELECTROSTATIC VOLTMETERS. Two dc-rf electro-static voltmeters are described in an 8-pg. publication. Bulletin 502 details Models LVE and KVE, both featuring automatic overload protection, "Unfiliar Suspension" capable of withstanding shock up to 100 gs, input impedance up to $3 \times 10^{15}\Omega$, true-rms response regardless of waveform or level, and flat frequency response over their total operating ranges. Cedar Grove Operations of Beckman Instruments, Inc., 89 Commerce Rd., Cedar Grove, NJ 07009. **225**

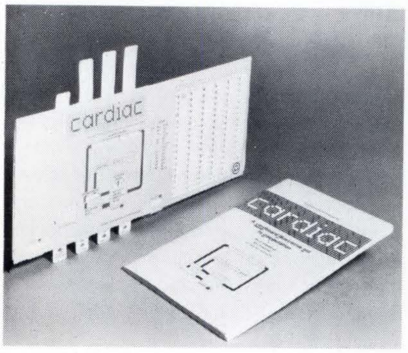
SWITCH AND KEYBOARD SELECTOR GUIDE. A handy "Design Engineer's Switch and Keyboard Selector Guide" has 200 standard types of snap-action switches, of matrix selector switches, thumbwheel & leverwheel switches and electronic data entry keyboards. This "pocket-size" brochure has 14 pages of illustrations, brief descriptions, sizes and electrical ratings. Cherry Electrical Products Corp., P.O. Box 718, Waukegan, IL 60085. **226**

WALL CALENDAR WITH 1973 MAJOR ELECTRONIC SHOWS. Texscan has prepared a large attractive 22 × 28-in. wall calendar with major 1973 show and exhibit dates for easy reference. Like the well-known Scotch ad has it: it's amazing how a little Scotch improves the flavor of water. In this instance, Texscan's line of dependable electronics instruments is visually improved by the lovely "Miss Texscan" seated smack in the middle of the calendar top. Texscan Corp., 2446 N. Shadeland Ave., Indianapolis, IN 46219 **227**

16-CHANNEL PORTABLE TEST OSCILLOGRAPH. The Series 870 by Hathaway Instruments is the subject of this brochure. The compact and portable instrument is an instant-start recorder with 16 channels and 12 speeds. Weighing only 35 lb with an integral handle, the 870 is well suited to requirements for simple operator controls, with high performance that includes 3000-Hz response and/or high-voltage isolation between channels. Hathaway Instruments, Inc., 5250 E. Evans Ave., Denver, CO 80222. **228**

INSTRUMENTATION INTERFACE. The DATOS 305, a programmable interface which outputs computer-compatible data is described in this brochure. In addition, it contains information of value for any type of instrumentation interfacing. Input levels and codes, the types of outputs needed to drive specific recording devices and output timing waveforms are all discussed. Data Graphics Corp., 8402 Speedway Dr., San Antonio, TX 78230. **229**

SOLID-STATE SWITCH DRIVERS. A wide range of TTL-compatible switch drivers with total switching times of less than 10 nsec are described in a 44-pg. catalog. The switch drivers are useful for series, shunt and series/shunt applications. They may be used in a variety of switch types (spst, spdt, sp3t, etc.) and come as standard, off-the-shelf drivers in two sizes: 0.5 × 0.5 × 0.1 in. and 0.6 × 0.6 × 0.1 in. LRC, Inc., 11 Hazelwood Rd., Hudson, N H 03051. **230**



A COMPUTER LEARNING SYSTEM. CARDIAC is a manually operated computer which comes complete with 53-pg. manual that explains it in terms of real computers. The student receives his "hands-on" training by operating CARDIAC through a series of 10 different programs which range from the simple to the complex. Learning this subject is enjoyable, simple and rapid, and the retention factor is excellent because of the "hands-on" facet. Comspace Corp., 300 Great Neck Rd., Farmingdale, NY 11735. **231**

DATA-ACQUISITION SYSTEM. A comprehensive 20-pg. catalog describes Datel's System 256, a mini-computer-compatible data-acquisition system. All electrical and mechanical specifications, performance and application data are listed. A wide range of options are outlined permitting a comprehensive system to be specified for applications to an instrumentation or control problem, or as an interface between an analog and digital computer in hybrid-computer systems. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. **232**

SOLID-STATE CHOPPERS. A 32-pg. catalog describes a line of solid-state choppers (analog switches) which include isolated, field-effect, basic, 60 and 400 Hz, high-frequency, high-voltage and vibrating choppers. All units are recommended for military and industrial applications. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343. **233**

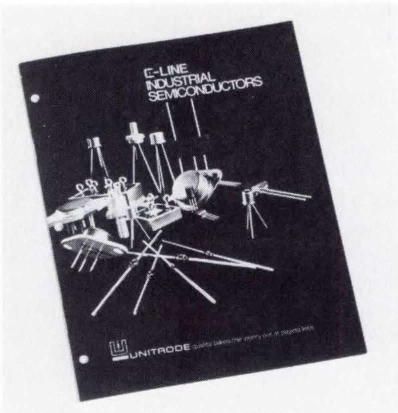
AUTOMATIC TESTERS. A comprehensive 12-pg. brochure presents technical details and application data on Datatron's four automatic test systems—the Model 4400 digital module tester, the Model 4500 high-speed functional tester and Models 4600 and 4650, pc card testers. Datatron, Inc., 1562 Reynolds Ave., Santa Ana, CA 92711. **234**

MULTI-ELEMENT SEMICONDUCTORS. This 96-pg. multiple semiconductor catalog (CC-406) covers devices with more than one chip in a package. It also details the packaging of diodes and transistors in integrated circuit compatible packages. The products discussed include duals, quad transistors, Darlington pairs, double-emitter choppers, diode arrays and diode matrices. Interchangeability guides are provided. Texas Instruments Inc., P.O. Box 5012, M/S 308, Dallas, TX 75222. **235**

CORE MEMEORY. This 4-pg. brochure describes the DMS-15 add-on core memory for the PDP 15. Any application of the DEC PDP 15 that requires accessing large amounts of 18-bit data or a large number of core resistent programs can use the DMS-15 and this pamphlet has the specs. Dimensional Systems, Inc., 393 Totten Pond Rd., Waltham, MA 02154. **236**

PRECISION LABORATORY ELECTROMAGNETS. The 24-pg. brochure entitled *Handbook of Precision Laboratory Electromagnets* explains terminology, selection procedures, operation and advantages of magnet systems. Specifications and typical field strengths are given for laboratory magnets ranging in size from 4 to 15 in. Specifications are also given for air core solenoids, electronic integrating fluxmeters and gaussmeters (NMR and Hall Effect). Walker Scientific Div., O. S. Walker Co., Inc., Rockdale St., Worcester, MA 01606. **237**

ND:YAG LASER CATALOG. A 4-pg. brochure summarizes high-energy, high-repetition-rate, neodymium YAG (yttrium aluminum garnate) laser systems. The brochure provides performance characteristics of the ILS Q switched lasers, laser rangefinders and welding systems. International Laser Systems, Inc., 3404 N. Orange Blossom Trail, Orlando, FL 32804. **238**



INDUSTRIAL SEMICONDUCTORS. The products in this catalog include: industrial zeners, programmable unijunction transistors for timing circuits, power Darlington transistors that provide a monolithic 2-transistor circuit, plastic SCRs and PUTs, and unique hybrid products like the power pulser, a thick-film hybrid circuit that delivers a high-power output pulse for a precisely timed interval. Other products include microwave diodes, rectifiers and bridges. Unitrode Corp., 580 Pleasant St., Watertown, MA 02172. **239**

HOW TO MAKE ACCURATE LOW-RESISTANCE MEASUREMENTS. A single-pg. applications bulletin describes methods for making rapid measurements of resistance in the range from 0.01 to 1Ω with accuracies of 0.06% or better. Both direct and comparative ratio measurement methods are given. Described are how measurements made using the 4-terminal ratio capability of the Hewlett-Packard Model 3450A/B digital voltmeter are faster than those made with hand operated resistance bridges generally found in standard laboratories. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. **240**

CATHODE-RAY TUBES. The 32-pg. publication helps buyers select a CRT with the optimum phosphor to meet any of a wide variety of application requirements. Spectral and persistence characteristics and typical applications are given for over 50 standard and special phosphors. A brief explanation of the use of phosphors in CRT screens and glossaries of terms and symbols are included. Westinghouse Electric Corp., Westinghouse Bldg., Pittsburgh, PA 15222. **241**

PHASE LOCKED LOOP INTEGRATED CIRCUITS. This free 76-pg. paperback explains phase locked loop monolithic integrated circuits. It contains a history, short glossary, description of the phase locked loop principle and PLL "building blocks." Major sections include explanations of general loop setup and tradeoffs, PLL measurement techniques, monolithic phase locked loops, expanding loop capability and specific applications. Signetics PLL Handbook, Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086.

MINI-MODULE dc POWER SUPPLIES. A 2-pg. data sheet describes Spellman's Mini-Module RMX Series of solid-state, regulated, high-voltage dc power supplies. It outlines the features of the series designed for use with photomultipliers, Geiger-Muller tubes, ionization gages, CRTs, image intensifiers, electron-beam systems, scintillation counters and many other applications. Spellman High Voltage Electronics Corp., 1930 Adee Ave., Bronx, NY 10469. **242**

RELAYS, STEPPERS, SOLENOIDS AND SOLID-STATE CONTROLS. This 20-pg. catalog has: a broad selection of basic relay types, including enclosed, open, power, reed, solid-state/hybrid and solid-state/time delay; 11 basic series of stepping relays; nearly 200 solenoids in a choice of pull type, push type or solenoid switches in tubular, box-frame, U-frame and laminated configurations and a wide variety of level detectors, logic steppers and protective sensors. Guardian Electric Mfg. Co., 1550 W. Carroll Ave., Chicago, IL 60607. **243**

TEMPERATURE-MEASUREMENT. The handbook contains the latest temperature-emf tables for thermocouples which are presently available only from Omega. These tables, released by the National Bureau of Standards as computer printouts, have been made an integral part of the handbook. Reference tables list all important thermocouple alloy combinations in both °C and °F. The handbook also contains useful temperature measurement data, facts, statistics and material properties about thermocouples which are vital to any scientist or engineer interested in temperature measurement. Omega Engineering, Inc., Box 4047, Stamford, CT 06907. **244**

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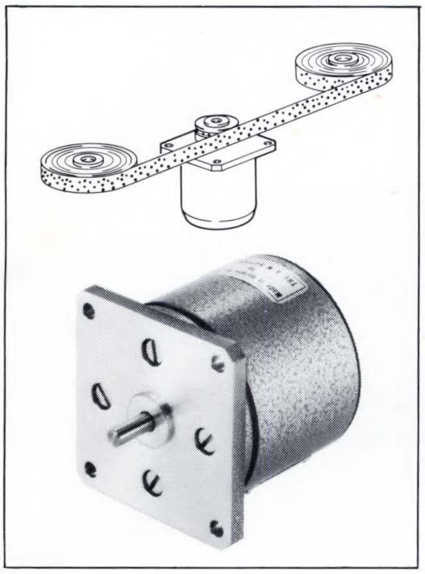

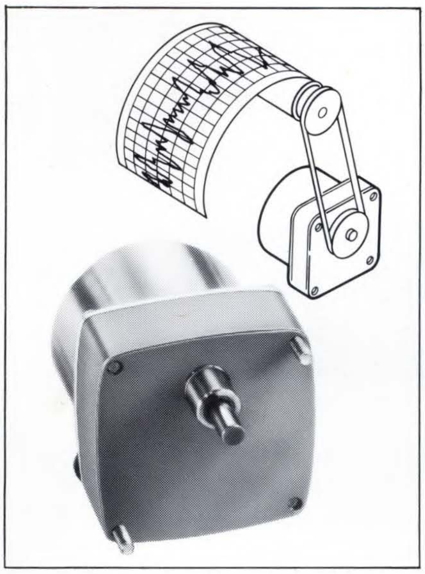

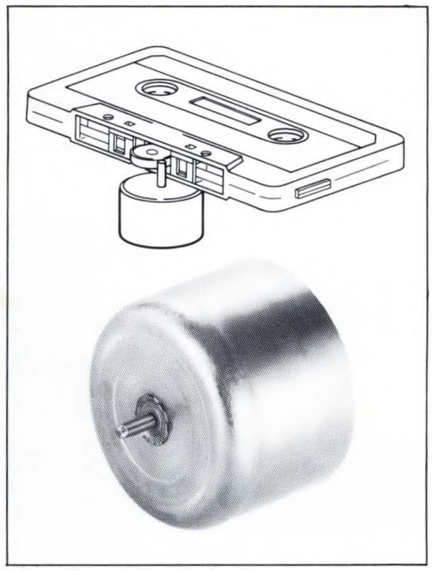

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